REPORT OF THE COMMISSION OF INQUIRY INTO FRASER VALLEY PETROLEUM EXPLORATION

David Anderson
Commissioner

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20 January 1991

TO HIS HONOUR THE LIEUTENANT-GOVERNOR IN COUNCIL

MAY IT PLEASE YOUR HONOUR,

Under Your Honour's Order in Council no. 695, approved and ordered on 2 May 1990, I was appointed a Commissioner to inquire into and report on a number of issues relating to proposals to carry out exploratory drilling for natural gas in the Fraser Valley region of this Province.

I have complied with your Order, and have the honour of submitting herewith my report.

Respectfully submitted,

David Anderson

David Anderson, Commissioner.

ACKNOWLEDGEMENTS

The number of people who have assisted this inquiry in one way or another is in the many hundreds. It would be quite impossible to list them all and give them the thanks that they deserve. Wherever information has been asked for, in Canada, in the United States, or in Europe, whether in person, by letter or fax, or by telephone, the responses have been unfailingly prompt and helpful. I am immensely grateful for this kind assistance and support.

I also wish to thank the many scores of Fraser Valley residents who turned out on hot summer evenings at the public meetings and technical hearings. The process adopted depended heavily on public participation, which was certainly forthcoming.

During the summer, organizing the commission process, arranging for commission field trips, and technical hearings, not to mention handling public inquiries, mail, and requests for information at the two commission offices fell to Commission Secretary Rob Tweedie, aided by Langley and Victoria office managers Elizabeth Svendson and Gillian Bass. Technical questions and the search for technical witnesses was the task of Tony Fogarassy. With the extension of the commission, their work and was continued with Eric Burkle, David Fenn and Sheryl MacDonald. Their cheerful assistance, often under difficult circumstances, made possible the successful conclusion of the inquiry.

Special mention must be made of Commission Counsel Doug MacAdams. The commission looked for the best counsel available in the province, and found that person in Abbotsford in the heart of the Fraser Valley. His ability to cover the various technical subject matters with witnesses, and at the same time to ask the questions uppermost in the mind of participants with very differing viewpoints, was a constant source of admiration.

I am deeply indebted to them all.

David Anderson, Commissioner

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INTRODUCTION

This Commission of Inquiry under section two of the *Inquiry Act* of British Columbia was established on 2 May 1990, in accordance with Order in Council No. 695 of the same date. The purpose of the inquiry was to look into matters of concern relating to the proposed three well exploratory drilling program in the Fraser Valley of the Fraser Valley Gas Project consortium, and what that program might lead to. Among these concerns were the threat to health and safety to residents of possible future underground natural gas storage and production of natural gas. Such matters in particular as the risks to groundwater in the valley, the risks posed by possible earthquakes, and the impact on agriculture, wildlife and fish, are spelled out in the terms of reference, the text of which is found in Appendix A to this report.

It should be noted that the terms of reference do not require the commission to recommend whether exploratory drilling should or should not be allowed. That is not an omission. The commission's task has been to consider objectively the technical matters of concern, and report thereon. A decision as to whether drilling should or should not proceed is a wider matter, which requires consideration of issues which can best be described as political, in addition to the technical matters dealt with below.

To handle the inquiry the commission established two offices, one in Langley, and one in Victoria. Staff consisted of Commission Secretary Mr. Robert Tweedie, Technical Advisor Mr. Tony Fogarassy, Office Managers Ms. Elizabeth Svendson and Ms. Gillian Bass, and Commission Counsel, Mr. Douglas MacAdams. With the extension of the commission, explained below, other staff were required, as some of the original staff had other commitments. In September and for the remainder of the year, Mr. David Fenn assisted with research, Mr. Eric Burkle took over as Commission Secretary, and Ms. Sheryl MacDonald took over as secretary in the Victoria office.

The commission was originally expected to report at the end of September, 1990. Due to delays resulting from a separate internal investigation of allegations of impropriety made by opponents of drilling, this date was later changed to the end of 1990.

After discussions with both the proponent consortium and the opposition group known as Friends of the Fraser Valley, the commission established the following schedule.

First, the consortium was requested to outline its proposed program at a public meeting. This was done in Aldergrove on 12 June 1990.

Second, nine public meetings were held in the Fraser Valley communities of Clearbrook, Cloverdale, Langley, Delta, Maple Ridge, White Rock, Chilliwack, Mission and Aldergrove. These meetings were well advertised in the local and Vancouver press. Childcare was offered to any person who required it. The meetings had attendance that ranged from 35 to 225. Their purpose was to explore public concerns and local knowledge that might be of assistance.

Third, research on those public concerns and on the issues contained in the terms of reference took place. This involved direct research by the commission staff, and by a small number of consultants in various expert fields. It also involved identifying technical witnesses for the technical hearings, and establishing a technical library of information for the public on the areas of concern. The public was involved in this work. The commission provided material to interested parties, kept the library open for the public at the Langley office, and where possible obtained material for the library that was suggested by members of the public. The commission also welcomed suggestions as to

who should be invited as technical witnesses, and what questions should be put to them. For example all five of the individuals proposed by the Friends of the Fraser Valley were invited, and all but one attended. Preparatory teleconferences with witnesses, which included participation by the consortium and by the Friends of the Fraser Valley, also took place.

The technical hearings were the fourth phase of the commission's work. Thirty-nine witnesses provided evidence on a wide range of topics of concern. The public was invited to attend these sessions, and childcare was again offered to those who required it. Further, during the course of the examination and testimony, the public was invited to inform Commission Counsel MacAdams of any questions that in their opinion should be put to witnesses. There were sixteen technical sessions, split between Delta and Langley. The transcript of these hearings was made available at the Langley office during September and October for anyone who wished to examine what had been said.

The next phase of the work was unanticipated, namely the two month investigation of allegations of wrongdoing described above. This involved a special hearing on 22 October 1990 in Delta. A further eight witnesses were heard, and eighteen affidavits and eleven other documents or collections of documents accepted. At the end of that investigation a Special Report was presented to the Lieutenant Governor on the conclusion of the investigation. In brief, the investigation showed that there was no substance whatsoever to the allegations, which were characterized as fabrications.

Following the Special Report the commission returned to evaluating the evidence, considering the summation reports on the evidence that the public had been invited to submit, obtaining more information where needed, and writing this report.

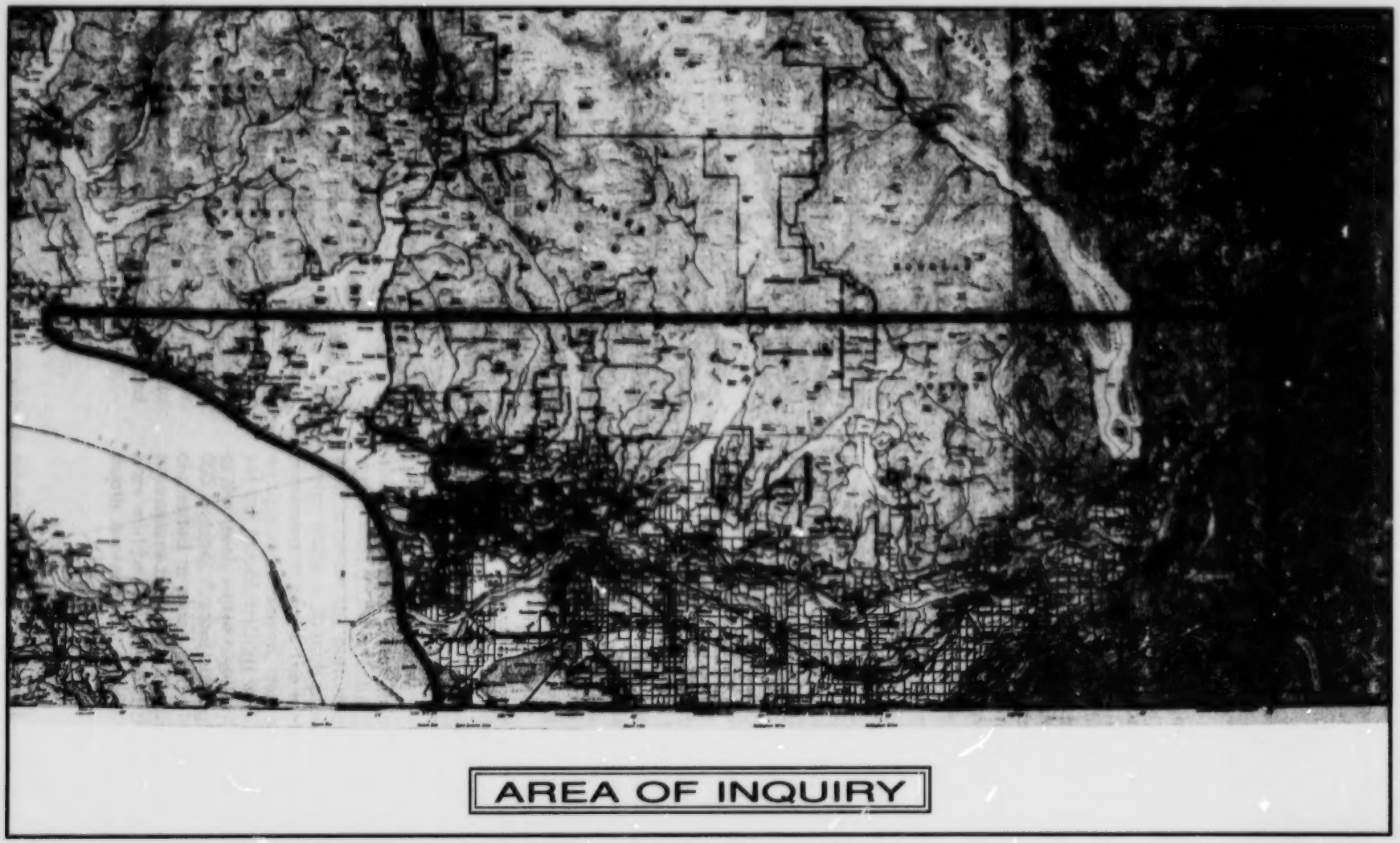


FIGURE 1

This report follows an eight month inquiry into the exploratory drilling proposals of the Fraser Valley Gas Project from May until December of 1990. The inquiry involved ten public meetings in various Fraser Valley communities; sixteen technical hearing sessions with 39 witnesses; visits by the Commissioner and staff to three Canadian provinces, seven states of the United States, and three European countries; a number of special consultants' reports; and an extensive review of literature and other research. The overall objective was to deal as fully as possible within the time available with the issues identified in the terms of reference and raised by the public as matters of concern.

Later in this report the role of this commission in the overall approval process is outlined. It should be noted and borne in mind that the issue before this commission is exploratory drilling of three wells, not whether there should be production of gas, or underground gas storage.

The technical examination of the issues involved has been thorough. The public has been fully involved in the process, which has been of great value to the commission.

The conclusions that emerge from the investigation are that the risks of exploratory drilling are slight, and the benefits, from the energy security, economic and environmental points of view may be considerable. While the words "may be" are not definite, exploratory drilling is inherently a "hit or miss" proposition, and the program may discover nothing of value. From the public point of view, the risks are very slight and the gains may be great.

This does not mean that the government should approve exploratory drilling in the Fraser Valley. The decision to allow, or not to allow, exploratory drilling in the Fraser Valley is inevitably one that takes into account more than the technical issues considered in the commission process. Political issues are important, and the final decision inevitably must be one based both on technical matters and on political concerns.

The Proposal

The Fraser Valley Gas Project consortium proposes to drill three exploratory wells, two in the Township of Langley and one near Boundary Bay in Delta. The location of the three sites are indicated on Figure 2. The Boundary Bay site is shown on Figures 3 and 4, and is 150 metres inside the Boundary Bay dyke. The area required for drilling is 1.6 hectares. The Murray Creek site is in the Township of Langley, near the Old Yale Road, and is shown on Figures 5 and 6. There is a residence 125 metres from this site, the closest residence to any of the three sites. Drilling will involve some 1.7 hectares. The Campbell River site is shown on Figures 7 and 8, and is close to the Canada/U.S. boundary in south Langley. The area required is also 1.7 hectares.

Drilling will involve an initial 26-inch hole, drilled with standard Fraser Valley water well drilling techniques. When this well is below the bottom of all nearby water wells, a 20-inch pipe will be cemented in place, the water well drilling equipment removed, and a petroleum rig set up. Initial drilling will be to the bottom of the fresh water aquifer (approximately 600 metres). A steel casing will then be cemented in place, and blowout preventers installed. Thereafter the well bore will be drilled until the proposed drill depth is reached.

All water wells within one kilometre will be tested before, during, and after the drilling. The water required for drilling will be trucked to the sites.

The proposed drilling program is discussed in Chapter 2.

Results of Exploratory Drilling

If the government approves drilling, and drilling does not result in a find, the three wells will be plugged, and the areas rehabilitated. From the experience of wells abandoned elsewhere, the commission is confident that this can be done to the point where no remaining evidence of drilling will be detectable two years later. If the three well program is not successful, further exploratory drilling can nevertheless be expected in the Fraser Valley. A thirty well program would probably be needed to effectively explore the area's geology.

If one of the wells turns out to have gas in commercial quantities, the amount of land that will not be rehabilitated will be in the neighborhood of 0.5 hectares. Five other wells will probably be drilled to maximize production from the field. These likely will be on a spacing of two per five square kilometres. In addition, there will be other facilities that can be expected to occupy from 2 to 4 hectares.

If natural gas is found in adequate deliverable quantities to improve the winter supply situation, independent storage is unlikely to continue to be of interest to the consortium.

If gas is not found in commercial quantities, but a favourable geological formation for an underground storage facility is found, the consortium can be expected to apply to the government to develop the facility. This will require a public hearing by the B.C. Utilities Commission before the proposal receives permission to proceed, or is rejected. At that time the Utilities Commission will have the technical data provided by exploratory drilling, it will have the actual proposals of the company, and it will have the comments of the public on these specific data. Thus it will be able to determine with precision the economic and environmental benefits, and the extent of risks, that may result from proceeding with the application.

It is inappropriate for this commission, on the basis of assumptions about a possible company application, and on the basis of assumptions about the geological data which will be provided by exploratory drilling results, to speculate as to what might be decided by the B.C. Utilities Commission at that time. The independent panel established by the B.C. Utilities Commission, armed with the drilling results and the actual geological data for the site, and aided by public evaluation of such material, is the appropriate body. This commission is not, and its terms of reference do not extend to that task.

Comments on storage in this report relate to what possible benefits it may provide, or what generic risks it poses. They are designed to assist in the decision as to whether or not exploratory drilling may lead to benefits that outweigh costs.

Scenarios resulting from the proposed exploratory drilling program are examined in Chapter 2.

Underground Natural Gas Storage

Economics

The benefits of natural gas storage are both economic and environmental. On the economic side, the figures of $30 million in savings to its customers and $35 million in savings to others, calculated by B.C. Gas on the basis that it can develop a natural gas storage facility for $104 million,

appears to the commission to be a realistic, although conservative, estimate.

Other methods of improving the winter supply of natural gas, such as LNG facilities, pipeline storage, propane supplements, mine shaft storage, expansion of the Kootenay connector line, or expansion of the Westcoast Energy Inc. line from the northeast, all appear to have higher costs, or otherwise have greater disadvantages.

The possibility of further storage for B.C. Gas exists at Jackson Prairie in the U.S., and this might be at lower cost; however the level of uncertainty that surrounds this is high, and is unlikely to be resolved until some years hence. The long lead time needed for energy projects requires that some alternative scheme be at least in the planning stage in case Jackson Prairie turns out not to be available in the mid-years of the decade. Such planning cannot be advanced beyond its present uncertain stage unless the geological data from exploratory drilling become available.

If British Columbia does not find a natural gas deposit of commercial size, or usable storage formations, near or in the Lower Mainland, and if this province is consequently required to increase gathering facilities and transmission facilities from the northeast to the southwest in order to meet winter demand, it is possible that British Columbia produced gas in the future could be selling in Washington State and Oregon at prices below what will be charged here. Further, the security of supply to industrial users in unexpectedly cold periods such as British Columbia has recently suffered, may be better in those states than in this province. This may have an effect on business confidence and location plans of industries that require security of energy supply.

There are many other factors involved in the pricing matrix, particularly the construction or expansion of competing pipelines in the U.S., and the availability of Albertan and Rocky Mountain supply, but the possibility of such a situation arising exists and should not be ignored. The commission wishes to draw attention in particular to the expansion plans of the Pacific Gas Transmission pipeline, and the effect this may have on existing and future B.C. export markets.

Thus the commission concludes that there are important economic benefits to determining whether underground natural gas storage or gas-bearing formations exist in the Fraser Valley.

Environment

From the environmental point of view, the advantages of expanding the use of natural gas in British Columbia are substantial. This is true not only on the local and provincial level, particularly to improve regrettably poor air quality in the Fraser Valley, but also as a part of this province's contribution to national and global objectives to reduce CO_2 and other greenhouse gas emissions into the atmosphere.

Exploratory drilling in the Fraser Valley will thus be welcomed by thoughtful environmentalists. The possible lower prices that might result from a commercial find or from an underground natural gas storage facility will have the effect of encouraging natural gas use, and discouraging the use of other, more polluting, fuels. Further, through increasing summer demand, it will result in more efficient recovery of gas in the northeast, with important conservation effects on gas reserves. It would also allow more efficient use of other resources which would otherwise be needed to expand the gas distribution and transmission system, assuming either that exploration is not permitted, or that it is permitted and storage is not found.

Finally, cheaper natural gas in British Columbia is a step toward the day when natural gas powered vehicles will be numerous, and available off the lot at lower cost, without conversion being

required. Cheaper natural gas will advance the day when properly adjusted natural gas engines are common, perhaps even the norm. Fuel price is the key to further change. The result of lower prices may be dramatic improvement in air quality in this region, and on the entire Pacific coast from Squamish to San Diego.

All other proposals for meeting the winter peak load have higher, often substantially higher environmental costs, other than the continued or expanded use of the Jackson Prairie facility, where environmental costs are likely lower.

The issue of underground storage of natural gas is discussed in Chapter 3.

Groundwater

With respect to petroleum exploration, the evidence presented at the commission hearings, and the experience of other jurisdictions visited by the commission allows for no other rational conclusion but that the risk of appreciable damage to groundwater is very slight indeed. Not only is the chance of a water or gas problem in or adjacent to the wall of a well very slight, but technology today can detect such problems quickly, and effective remedial action can be taken.

Such remedial action with modern technology is virtually certain to be able to deal with the problem without ill effects to the groundwater. Finally, even in the unlikely event that an appreciable amount of methane does enter an aquifer, its characteristics are such that it can be expected to vent upwards and away, unlike pesticides, herbicides, agricultural run off, gasoline, or heating oil, none of which can be expected to act in a manner that might restore the quality of the water.

Thus the chance of groundwater damage from exploratory drilling is remote in the extreme. When compared to the appreciable groundwater degradation that can be expected from existing sources, exploratory petroleum drilling is the least by far of serious concerns.

There are at present very serious threats to Fraser Valley groundwater by reason of agricultural activities, specifically pesticide and herbicide run off, and extensive use of chemical and manure fertilizers. Equally important are risks from leaking gasoline tanks at service stations and leaking (and often abandoned) heating fuel oil tanks. These threats to groundwater are also threats to soil; toxic soil contamination along with groundwater contamination is almost certainly taking place at the present time. Finally, improperly maintained water wells and old and abandoned water and petroleum wells constitute yet another avenue through which contaminants can reach the aquifers of the area.

These are serious threats, with a serious chance of rendering the groundwaters of the Fraser Valley unusable some decades hence. The commission most strongly urges new legislation to protect groundwater, such legislation to be accompanied and integrated with new toxic soil legislation. Further, it most strongly urges that a program of groundwater protection be undertaken on a priority basis, to deal with the existing risks, as far as that is possible. It is recognized that this will be a very expensive undertaking, but delay can only increase the cost. Inaction means that the current high risk to groundwater continues to increase.

The impact of exploratory drilling on groundwater in the Fraser Valley is discussed in Chapter 4.

Earthquakes

The information presented to the commission on earthquake risks is similar to that presented on groundwater, namely that current earthquake risks are relatively high to lives, private property and public infrastructures in British Columbia, particularly in the Richmond area of the Fraser Valley, but that the risk

of earthquake damage to existing or possible future natural gas installations is, in relative terms, slight.

California and Japan provide examples of petroleum facilities weathering earthquake shocks with surprisingly little damage, despite the fact that the facilities often lacked the design or equipment that is available today to reduce earthquake effects.

The conclusion of the commission is that any petroleum facilities should be designed to California standards, but that with such design, and with flexible steel and plastic pipe for transmission lines and gathering pipelines if gas happens to be found, the risk of appreciable gas leakage and fire as a result of a serious earthquake is slight.

The commission believes that the greatest risk to an underground natural gas storage facility during the earthquake would be from the hydrostatic pressure fluctuations, which would cause the gas bubble of a storage facility to fluctuate in size. This could conceivably cause the gas storage facility to release some gas during the earthquake from the caprock spill point. To prevent this earthquake-induced fluctuation from pushing the bubble beyond the spill point is simple. The gas contained in an underground natural gas storage facility in the Fraser Valley, were one to be established, should be at a higher elevation above the spill point than would be usual in an area where earthquake risks are less.

The risks of earthquakes on petroleum facilities and underground natural gas storage areas are analyzed in Chapter 5.

Health and Safety

Blowouts

Perhaps the greatest health and safety concern of Fraser Valley residents was the risk from blowouts. The commission has concluded that the chance of a blowout is slight. Alberta figures suggest it is below fifteen for every ten thousand wells drilled. From the geological and pressure information provided by past drilling in the Fraser Valley, this is likely to be a high figure for the exploratory wells proposed by the consortium. Further, the procedures the consortium intends to use in the Fraser Valley, not generally in use in Alberta or northern B.C., will reduce risks further. The commission is of the view that the blowout risk for the consortium's three well program would be no higher than one in five thousand.

If a blowout occurred, the possibility of the emerging gas being sour gas is very slight. The information obtained from past deep wells drilled in the geological formation known as the Georgia Basin, which includes the Fraser Valley on both the U.S. and Canadian sides of the border, and the eastern shore of Vancouver Island, suggests strongly that no sour gas is present.

If a blowout occurred, and sour gas is not present, the gas that erupts can be expected to quickly dissipate in the atmosphere, or be burned. The distance from the well site that might be affected by this is not great. Calculations on the dispersion of sweet, dry natural gas show that the maximum concentration of methane that can be expected 30 metres downwind of the well would be 1.2%. This is significantly below methane's lower flammability limit of 5% concentration in air.

If sour gas is present, standard practice is to burn it until the blowout is brought under control. This is rarely hazardous; what hazard exists is essentially to the crews on the rig.

If a blowout occurs, and if sour gas is present, and in the highly unlikely event that ignition of the gas fails, there is risk to nearby residents. The emergency evacuation plan prepared by the consortium under the supervision of the Ministry of Energy, Mines and Petroleum Resources would then go into effect. The commission believes that the plan is appropriate under such circumstances.

It should be noted that 200,000 wells have been drilled in Alberta, and 7,000 in British Columbia. To date the experience of these jurisdictions has been that of other North American jurisdictions. While blowouts have sometimes killed members of rig crews, and have sometimes killed personnel attempting to bring the blowout under control, the commission found no evidence that a blowout has ever killed a nearby resident.

The safety and health issues associated with petroleum exploration are discussed in Chapter 6.

Methane

Methane is the principal component of natural gas. Methane is non-toxic and if ingested is not a risk to human health. Methane is generated naturally in the body of humans and other animals. All humans daily emit methane into the atmosphere.

In confined spaces, at certain concentrations (roughly 5 to 15%), methane can explode. Thus a leak of methane can be hazardous if it enters a home and accumulates. The greatest risk of this is from careless operation of a gas appliance in a home. If methane concentrations in the atmosphere are so high that they exclude oxygen, methane, like any other gas, will smother.

With normal precautions, the methane risk to the health and safety of residents of the Fraser Valley from an underground natural gas storage facility or natural gas production facilities is extremely low. Were an underground natural gas storage facility to be established, a methane detector (similar to a smoke detector) should be available to those who live above such facilities who express concern as to safety. The commission found no evidence that any person living above an underground natural gas storage area anywhere in the world has suffered injury, let alone death, from a leak or other accident attributable to the facility.

The effects of human exposure to methane are also described in Chapter 6.

Land and Resource Impacts

Agriculture

The commission considered the impact on agriculture of the three exploratory wells, and any future petroleum developments in the Fraser Valley with great care. The greatest risk appears to be noise problems associated with drilling, or with the compressors of a gas transmission pipeline or an underground natural gas storage facility on particularly sensitive animals such as mink. The problem, however, is a generic noise problem, not a petroleum industry problem, and should be dealt with by appropriate general municipal noise suppression by-laws or by general provincial regulations. The commission is of the view that the Fraser Valley Gas Project consortium, perhaps with some help from the B.C. Petroleum Arbitration and Mediation Board, will have little difficulty in handling reasonable concerns in this regard.

With respect to land use, the commission is of the view that if the exploratory program is approved and no commercial quantities of gas or a suitable underground gas storage formation are found, the impact on agriculture will be the temporary removal of approximately 5 hectares of land for one year. Agricultural production on these 5 hectares is expected to be equal to the pre-drilling levels within two years. If gas is found in commercial quantities, and petroleum development takes place, six hectares of land might be taken by the industry, some of which could be expected to be taken from the agricultural sector.

On the other side of the ledger, the petroleum industry is likely to wish to have agricultural or forested land adjacent to its facilities. It is thus likely to be a positive factor in areas near its facilities in reducing the rate of shift of agricultural land to subdivisions and other non-agricultural uses. Further, the income that farmers and other landowners will receive from petroleum production can be

expected to result in a greater willingness on the part of farmers and their families to keep land in agricultural production. The overall result is that the industry can confidently be expected to be an ally of the Agricultural Land Commission and of the land-based agricultural community in its efforts to maintain agricultural land in the area. The impact of the industry will be positive.

For non soil-bound agriculture (generally operations done in buildings, such as poultry farming, mushroom growing, or greenhouse crops) improved supplies of natural gas at lower rates can be expected to be an advantage where building heating is required, particularly, as in greenhouses, where double glazing or other insulation may be prohibitively expensive, and where interrupted energy in winter may destroy the crop.

The commission concludes that overall, the presence of the petroleum industry in the Fraser Valley will be positive and of benefit to the agricultural community.

The impact on agriculture of petroleum exploration and any subsequent development in the Fraser Valley is discussed in Chapter 7.

Fish and Wildlife

The exploratory drilling, possible subsequent development, or underground natural gas storage poses very little risk to fish, provided always that proper procedures are adopted and carried out.

The Salish Sucker in particular should not suffer adversely from petroleum exploration, development, or from underground natural gas storage. However this species is facing extinction from habitat loss in the Fraser Valley. The commission most strongly urges that the government adopt effective measures to reverse this habitat loss, to protect the Salish Sucker, and to introduce effective endangered species legislation in the province.

Overall, the petroleum industry has had an uneven record in protecting the wildlife of the areas in which it operates. This attitude changed in the 1980s, as the industry attempted to grapple with its lack of popularity with the public. Its record is now fair. Conoco in particular has been an industry leader in this regard.

This positive attitude can be expected in petroleum activities in the Fraser Valley. Further, for the reasons outlined above when discussing agriculture, the industry will likely wish to locate at least some of its facilities with buffer zones of agricultural land, parks, or other areas with sparse human populations. Thus the industry will likely be a positive force in protecting habitat for animals and birds. Given the experience of the industry during the past decade, it can be expected as part of a public acceptance program to go beyond passive protection of these areas, and embark on active wildlife habitat restoration and enhancement.

The commission has concluded that the overall impact of the presence of the industry in the Fraser Valley on wildlife can be expected to be positive.

The impacts of the exploratory program on fish and wildlife are discussed in Chapter 7.

Archaeological Impact

Drilling petroleum wells takes little surface area, and results in a temporary disruption of land. It has far less impact on the surface or layers immediately under the surface than subdivisions, or the construction of commercial buildings, or road construction, or agriculture. The exploratory drilling program of the consortium can be expected to have no adverse impact on archaeological sites in the Fraser Valley.

The impact of the drilling program on archaeological resources is also examined in Chapter 7.

Aesthetics

The commission regards aesthetics as the most likely problem area if exploratory drilling were allowed in the Fraser Valley, or if such drilling were to lead to production or underground natural gas storage.

A drilling rig is 40 metres high and will run night and day for up to six weeks. There will be traffic, lights at night, noise, and visual impact. While noise can be reduced through noise suppression engineering, traffic routed to non rush-hour times, and lights shielded, there is still impact. Further, little can be done about the visual impact of the rig, which will be similar in height and visibility to the microwave towers that currently exist in the area.

Compensation for aesthetic impact is possible, and should drilling be permitted, negotiations and compensation discussion might be undertaken. However the commission notes that experience elsewhere on energy facility siting decisions makes clear that there is no point in embarking on such discussions until a firm and final decision on whether drilling is to take place has been made. If such a decision is made, there are many examples of successful discussions leading to amicable settlements. Again, if drilling is permitted, a public advisory council would appear to be a useful tool.

From experience in other jurisdictions, particularly California, Italy, Britain and France, the commission is of the view that modern techniques can dramatically reduce the aesthetic impact of drilling. It cannot, however, be reduced to zero and eliminated. The commission is aware from personal observation that Californians in homes worth $300,000–$600,000 do not move out when workover drilling rigs drill 10 to 30 metres from the windows of their houses. The commission is also aware from personal observation that Western Europe's largest on land oil field was established recently under a tourist area which welcomes over five million visitors a year, that this was done with few complaints or impact on the public, and that, now that it is completed, few members of the public even know that it is operating. This does not mean that drilling and petroleum production will be acceptable in the Fraser Valley. It means only that it has proved possible in sensitive areas elsewhere, in somewhat similar conditions.

Aesthetic impact is a subjective matter, and subjective matters are not amenable to the type of objective, expert study that this commission has been engaged in. The inquiry process can search out and report on experiences elsewhere. It can determine questions of fact. These are objective questions, suitable for expert testimony and opinion. What it cannot do is advise the government whether such levels will be acceptable to individuals currently hostile to the proposals of the consortium. This has become a political matter, which politicians must decide.

The issue of aesthetics is discussed in Chapter 8.

Property and Ownership

Two 1988 studies in Alberta, one done by Deloitte Haskins & Sells and the other by Jim Lore & Associates conclude that sour gas facilities have no noticeable effect on property prices, whether farmland or recreational/residential land. As sour gas is far more dangerous, and has far more aesthetic impacts than sweet gas, and as it is highly unlikely that sour gas will be found in the Fraser Valley, these studies can be considered to be worst case scenarios as far as the Fraser Valley is concerned.

Information from many other jurisdictions was examined to determine whether the existence of an underground natural gas storage facility will affect property prices. The conclusion of these other jurisdictions is that it will not have a long-term

detectable effect on residential property values, but will tend to increase subsurface and agricultural land values.

Where property prices can expected to be depressed is in the short run, where such a facility has been proposed, and where opposition to it has increased citizens' concerns over the risks that such a facility will pose. If such a facility is subsequently established, experience will demonstrate that the level of fear has been excessive, and the reduced property values can be expected to return to the average of other similar properties not over such a facility. This will happen approximately two years after the facility commences operations.

The commission has concluded that it is possible that residential property values may decline temporarily in the Fraser Valley as a result of publicity surrounding the possibility of the establishment of natural gas facilities, although there is no clear evidence of this at the present time.

Property and ownership issues are examined in Chapter 9.

Insurance and Liability

The issue of insurance, and the possible lack of coverage in the case of the establishment of an underground natural gas storage facility, was canvassed at length, both by an investigation of a professional insurance and risk consultant, and by inquiries of commission staff at the petroleum facility sites visited in Canada and abroad. The conclusions of both the investigator and the commission inquiries were that normal insurance for homeowners is available above natural gas storage facilities, at premiums that are no different from the premiums of homes not over such facilities.

Further, it was determined that no insurance is presently available to homeowners to cover against the risk of groundwater contamination from any source; given the high risk to Fraser Valley groundwater from pesticides, herbicides, agricultural fertilizers, gasoline from service station storage tanks, and from abandoned fuel oil tanks, this lack of insurance coverage is understandable.

The commission recommends that if permission to proceed with drilling is given, insurance coverage from the risk of groundwater contamination from drilling be provided by way of a captive insurance company, established under existing provincial legislation. This would provide a financial guarantee to the residents in the valley who are concerned about possible groundwater damage, and at the same time provide a legal vehicle for the consortium to use to back up their commitment to compensate and guarantee water supplies in the event of a groundwater problem arising from their activities.

Finally the commission notes that the insurance industry is highly specialized. Specialists in automobile insurance, for example, are unlikely to be aware of the coverage that is available from companies that specialize in the petroleum field.

With respect to liability, the commission recommends a series of proposals to bring the *Petroleum and Natural Gas Act* in line with the *Waste Management Act*, and other provincial statutes. These recommendations, taken as a whole, increase liability of companies and company officers, and increase penalties for non-compliance. Other suggested amendments have as their objective the establishment of a legal framework for the existing underground natural gas storage facility in British Columbia at Aitkin Creek, and for any other such facilities that might be established.

Insurance and liability are examined in Chapter 10.

Spacing, Minimum Distances and Exclusion Zones

Spacing is the term used to describe the distance between wells. The purpose is to

control well density, and thus maximize the production from the hydrocarbon pool. Minimum distance requirements are for a different purpose, namely environmental, aesthetic, or safety reasons at the surface. Thus minimum distance requirements prohibit drilling within a certain distance of a residence, a road, a river, or an airport.

In accordance with the terms of reference, both spacing and minimum distance requirements were examined by the commission. Spacing requirements are currently one gas well per two and a half square kilometres, and one oil well per section, which translates to eight for every five square kilometres. These are not absolute limitations, as variation is permitted to achieve the objective of maximizing the return from a field. The commission is of the view that this flexibility is important, and thus there is no reason to alter the existing spacing requirements.

With respect to minimum distance requirements, the situation is similar. At present a well cannot be drilled closer than 80 metres to a building. For special wells, which includes all the exploratory wells in the Fraser Valley, the distance is 100 metres. In addition, the minimum distance to a river or other waterway or a road is 100 metres. Special minimum distances apply in the case of airports. The commission is of the view that the public has been successfully protected by minimum distance standards in the past, and notes that improvements in technology combined with unchanged minimum distance requirements have increased the level of safety and aesthetic protection for residents. Some minor changes are recommended; however in general the commission believes no change should take place for the province as a whole, and further, that there is no reason to treat the Fraser Valley differently from other parts of the province with respect to minimum distance.

With respect to exclusion zones, the commission has carefully considered all proposals made to it that various areas of the Fraser Valley be excluded. None have had such special features as to require special exclusion from the present system. The commission notes that minimum spacing requirements in effect create large exclusion zones in the populated neighborhoods in the Fraser Valley at the present time. It also notes, and approves of, the flexibility in the current *Petroleum and Natural Gas Act*, which permits variations in the case of special circumstances. Parks, schools, hospitals, airports, waterways and harbours, GVRD reservoirs and watersheds, roads and residential areas are adequately protected by the present system.

The conclusion is that this flexibility, combined with the current restrictions, allows for appropriate limitations on drilling to protect the population and any special values that might exist in a particular case. The commission does not believe that blanket exclusion zones are warranted at the present time.

Spacing, minimum distance and exclusion zones are discussed further in Chapter 11.

Petroleum Legislation and Regulation

The commission carried out an examination of the legislation governing petroleum industry activities in British Columbia, and compared the legislation here with that of other jurisdictions with long experience of the industry, particularly Alberta, Ontario, Pennsylvania, and Michigan.

The commission has recommended a number of measures, the two main objects of which are first to bring the *Petroleum and Natural Gas Act* in line with other provincial legislation, particularly environmental legislation, and second to improve the legal protection of individuals who may be impacted by petroleum industry activity.

The commission considered the question of whether changes to legislation are needed to provide further protection of surface landowners in the event that part of their properties are temporarily required for an exploratory drilling program, or in the event part of their land is permanently alienated for a production or storage facility. This issue has many aspects which affect other statutes and other expropriation situations. Road allowance expropriation is an example. The commission notes that no documented examples of difficulties in this regard were presented to it by members of the public. It has concluded that any issue involving temporary or permanent expropriation can be expected to be contentious, and that any study of the matter should not just deal with petroleum industry activities, but should deal with all facets. The commission did not have such a mandate, and thus offers no conclusions or recommendations on this issue.

Proposed changes to petroleum legislation and regulation will be found in Chapter 12.

Fairness Issues

The terms of reference, and in addition the discussions of the public meetings, raised a number of ethical issues, described in the report as issues of fairness. Perhaps the most frequently mentioned was why should Fraser Valley residents take risks with respect to exploratory drilling, natural gas production and storage, the benefits of which would largely accrue to others who live elsewhere.

Some, but by no means all of these questions are addressed in Chapter 13.

Public Participation

An important objective of the commission was obtaining a high level of public participation. Through public meetings and less formal contact, the public of the valley had extensive opportunities to outline their concerns over petroleum exploration, development and underground natural gas storage. The commission encouraged members of the public to assist it in identifying those who would be of assistance as witnesses, in identifying lines of questioning that should be addressed to witnesses, and finally, at the public hearings, in determining what questions should be asked by Commission Counsel. The public was invited to submit views as to what should be contained in this report. The commission is pleased that it was possible to carry out such an open, participatory inquiry.

The commission regrets that towards the end of the technical hearings the Friends of the Fraser Valley chose to boycott the commission's activities. The withdrawal of this special interest group was not, however, unexpected. The patterns of action of such groups in other energy facility siting deliberations elsewhere in North America have been similar. Past experience suggests that open and impartial technical analyses, with the ultimate outcome or recommendation dependent on technical evidence rather than on a predetermined belief, are unlikely to satisfy those who hold such a fixed belief as to what the outcome should be. Further, expert or technical opinion attempts to assess risks on the basis of expected injury, illness, or mortality. Public perceptions of risk are often based on fears independent of such criteria.

Finally, research indicates that such disagreements about risk do not dissolve in the face of conflicting evidence. Strong initial views are resistant to change because they influence the way subsequent information is interpreted. Evidence only appears reliable if it supports the initial belief; contrary evidence is dismissed as erroneous, unrepresentative, or unreliable. The rejection of the open process of the

commission by the Friends of the Fraser Valley is an interesting example of this well recognized and common pattern of reaction by such special interest groups.

The Special Report

As outlined in the commission's Special Report of November 1990, there has been vigorous and organized opposition to the proposals of the consortium. The effect of this has been mixed. As noted later in this report, this watchdog role has helped the commission identify the issues of concern, identify witnesses who might be critical of the drilling program, and has helped it in determining what lines of questioning should be followed at the technical sessions.

On the other hand, as detailed in the Special Report, some opponents have resorted to spreading untruthful allegations of improper and illegal behavior by civil servants and by proponents of drilling. In November, subsequent to the Special Report, they resorted to further allegations of misconduct, against the staff of the commission. This has resulted in yet another investigation, this time by the Law Society of British Columbia. In a decision on 7 January 1991, the Law Society concluded that there was no evidence to support these allegations.

Unfortunately these two separate investigations of these allegations have delayed this report, from October of 1990, to January of 1991. The commission regrets these delays, but regards them as an unfortunate price of the open and public process. Sadly but perhaps inevitably in such processes, some will succeed in abusing the opportunities for constructive participation that are provided to them.

Reaction to Report

No doubt following the release of this report further technical studies will be asked for. The commission does not believe such studies will be helpful. No amount of further study and technical analysis can lead to a more open attitude, or the acceptance of technical reports by those who reject the validity of technical analysis. The objections of the Friends of the Fraser Valley have been shown to be based on concerns that cannot be dealt with by technical analyses.

Public Reaction and the Subsurface Rights Issue

Public opinion in the Fraser Valley has not been unanimously opposed to the proposal of the Fraser Valley Gas Project. Those who support the proposal have been content to allow the Fraser Valley Gas Project consortium to handle the subsurface owners' interests, and have not established a similar organizational vehicle as the Friends of the Fraser Valley. Thus there has been an imbalance in press coverage of the issues involved. A decision to reject the proposal of the consortium will change this, and determined public reaction can be expected from many thousands of people. Compensation for the 240,000 Fraser Valley residents who own subsurface rights and who would regard such a decision as confiscation of their property probably would be required, a process that may take from one to two hundred million dollars, perhaps a great deal more. Whatever sum of money is considered adequate by the government, almost certainly it will not be considered adequate by many of those whose legal rights will be affected. The compensation process will take a great deal of time.

Chapter 14 provides a discussion of these public issues.

Background and Recommendations

Chapter 15 of this report provides descriptive and background material on the Fraser Valley, its land use patterns,

geological characteristics, as well as a history of drilling in British Columbia and the valley. Its purpose is to provide the reader with a general understanding of the various environments in which the proposed drilling program was considered.

The specific recommendations made in this report are set out in Chapter 16.

Proposed Drilling Program

The Fraser Valley Gas Project consortium proposes to drill three wells, two in the Township of Langley and one near Boundary Bay in Delta. The three proposed sites are depicted in Figure 2.

Anticipated drilling time would be four weeks each for the two 3,200 metre Township of Langley wells, and fifteen days for the 1,600 metre Boundary Bay well.

The following descriptions are from the submission to the commission of the Fraser Valley Gas Project consortium and its application under the British Columbia *Petroleum and Natural Gas Act* for approval to explore for hydrocarbons in the Fraser Valley.

Site Descriptions

Boundary Bay Site (Delta)

The Boundary Bay site, shown on Figures 3 and 4, is situated immediately east of a small airfield in south Delta, 150 metres inside of the Boundary Bay dyke. The property is presently leased to a dairy farmer, and is located within the Agricultural Land Reserve. A barn and other farm buildings are located 165 metres from the well site, and various aircraft servicing businesses and an airstrip are located 300 metres from the well site. Other farms are located along 104th Street.

The area required for exploration involves 1.6 hectares (ha), including well site, work space and access road. The proposed drill site occurs in the middle of a pasture behind the farm.

Murray Creek Site (Township of Langley)

The Murray Creek site, shown on Figures 5 and 6, is located off Old Yale Road in the Township of Langley. One residence is located 125 metres west of the well site, and two other residences are located 150 metres to the south. The property is located within the Agricultural Land Reserve. The exploration phase will require 1.7 ha of land.

The proposed drilling site is located on gently sloping, abandoned pasture land. One large broadleaf maple tree next to the well site will be removed along with a small area of deciduous trees on the eastern property boundary.

Campbell River Site (Township of Langley)

The Campbell River site, shown on Figures 7 and 8, is situated near the Canada - U.S.A. border, within the Township of Langley. It should not be confused with the city on Vancouver Island. The property is a privately owned dairy farm within the Agricultural Land Reserve. The area required for exploration is 1.7 ha, including the access road.

The proposed drilling site is located on agricultural pasture at the base of a prominent knoll. The uphill area is forested with red alder, red cedar, birch and Douglas fir. The proposed site will require removal of 0.3 ha of timber.

Cave Creek is located 95 metres from the proposed drilling site. At least two intermittent, shallow channels have been formed from surface runoff draining the hillside. Cave Creek is classified as a fish-bearing stream by the Ministry of Environment.

Site Preparation and Access

Surface leases will be arranged with the property owners and tenants. All of the proposed sites will be fenced for security purposes. In addition, a 24 hour guard will monitor access. Site preparation will involve removal and stockpiling of topsoil. At the Boundary Bay site, about twenty

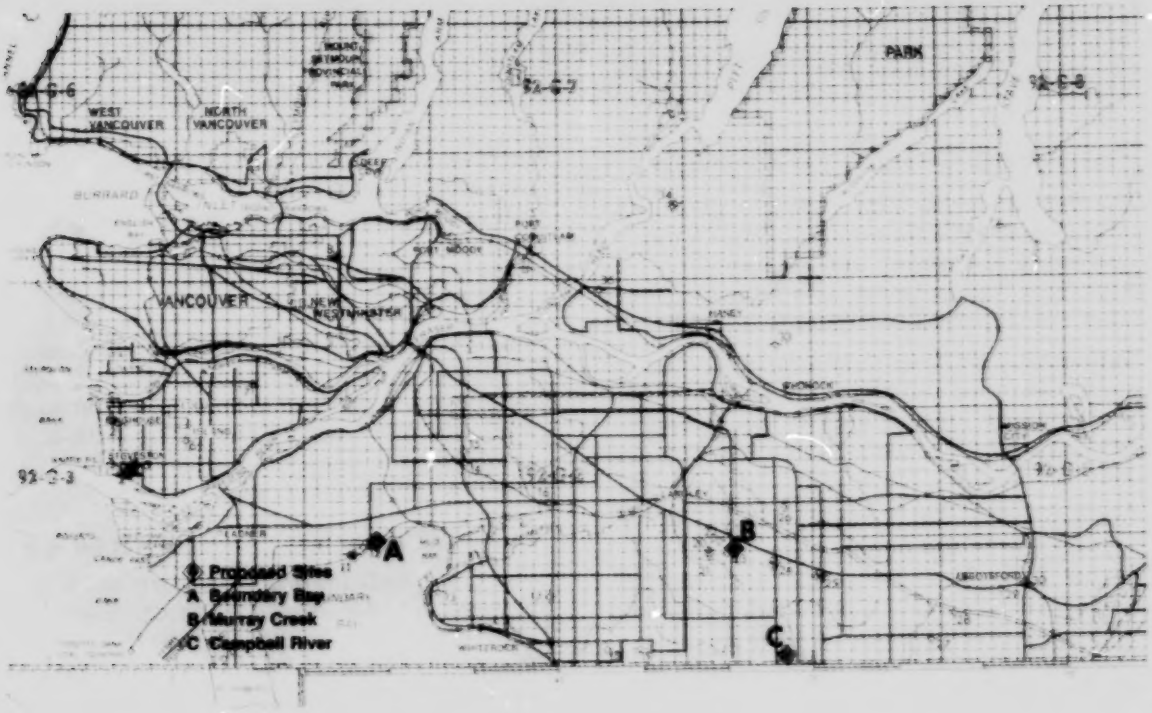


FIGURE 2 — Proposed Drilling Sites in the Fraser Valley.

centimetres of soil will be removed and temporarily replaced with (Hemfir) hog fuel. At the other sites, local gravel will be used as a base for the work area and access road.

Drilling Operations

After a drilling site is constructed, the drilling operations will begin with the drilling of a 26-inch hole. The initial drilling for a conductor pipe will be similar to drilling a water well, using air and foam instead of mud. For the Campbell River and Murray Creek sites, a 20-inch diameter conductor pipe will be set in place using a local water well rig. It will be set to a depth below all adjacent water wells and the pipe will be cemented in place. This procedure should take approximately one day. The water well rig will then be removed and replaced with an oil drilling rig. Preparation for further drilling will take three to five days.

Traffic for construction of the rig will require 35 to 40 truckloads of equipment. After construction, traffic will involve crew changes, transportation of casing strings, and other drilling equipment. Timing of delivery and removal of equipment will be arranged to minimize problems with local traffic.

A 12¼ inch bit will then drill a bore hole to 610 metres depth, and 9⅝ inch steel casing will be cemented in place. This procedure will take two days.

The well bore will therefore be cemented from top to bottom, preventing inflow of groundwater and outflow of drilling fluids. Upon installation of blowout preventers, round the clock drilling will resume, in a 8¾ inch hole, until the proposed drill depth is reached.

In order to be certain about the effects of drilling on local groundwaters, chemical water quality analysis will be undertaken

on domestic wells in the vicinity of the proposed Township of Langley well sites. At Boundary Bay, domestic water is supplied by the Greater Vancouver Water District as aquifers in the area are brackish to saline. Testing will occur before and after the drilling operations and, if need be, during drilling. All water wells within a one kilometre radius will be tested.

Clean-up and Reclamation

Immediately after the exploration program, all of the facilities will be removed and clean-up and reclamation will begin. This will involve any necessary recontouring of the site, replacement of topsoil and reseeding and revegetation as required by regulation and arranged with the landowner. With an unsuccessful well, access roads may also be removed and the ground cover restored. With a successful well, the temporary work space is restored and revegetated within two years. The 1.2 ha work space will be reduced to the 0.5 ha needed for the producing well and associated equipment.

Drilling Fluids Processing

The drilling fluids and muds will be processed using a closed-loop, centrifuging, de-watering system. This system will remove the solids from the drill muds and process the liquids to ensure removal of clay material, while also recovering clean water for reuse in drilling operations.

Following water removal, the drilling muds will be transferred to a rig shaker for primary removal of large solids. The remaining muds then will be pumped into mud tanks next to the rig. Buried steel tanks will be used for a sump at all three sites.

From the buried tanks, the fluids, with fine colloidals will be flocculated and pumped to the centrifuging unit for further liquid/solids separation. The remaining liquid will be tested for metals and have a 96 hour fish bioassay prior to release. Clean waters are then transferred to storage tanks.

Disposal of Drill Muds and Solids

The remaining drill mud solids will be comprised of rock chips, sand, silt, shale and/or clay. The remaining drill mud solids will be trucked from all of the sites to the Burns Bog landfill site or other sites as specified by the Ministry of Environment. It is estimated that 75 tandem truck loads will be required to transport the waste solids.

Water Supply

The deepest wells will require about 490 cubic metres of water. At Boundary Bay, the first location to be drilled, about 260 cubic metres will be purchased from the Greater Vancouver Water District supply. The water will be recycled at the drill sites in the Township of Langley.

After drilling, the processed water will be tested to meet Provincial standards and will then be trucked to an approved disposal site.

Drainage and Sediment Control

Well site preparation will include measures to control runoff. Excavation will be required at the Campbell River and Murray Creek sites. The drainage and sediment controls include:

(1) construction of a dyke around the well site;
(2) construction of a runoff diversion ditch and where necessary a catchment pit to control runoff and sediment downslope of well sites;
(3) placement of culverts across access roads and other locations where necessary and setback of equipment and materials from watercourses; and
(4) site recontouring and reclamation.

Future Developments

Subparagraph 2 (b) of the terms of reference of the commission requires the commission to provide comment on what may lie beyond the exploratory drilling program, were that to be approved and undertaken.

Expected Developments in the Event of No Significant Discoveries

If the proposed drilling program of the Fraser Valley Gas Project were undertaken, and no significant discoveries made, the commission is of the view that nevertheless there will be further applications for exploratory drilling in the Fraser Valley in the years ahead.

The reason for this conclusion is the limited nature of the exploration carried out in the Fraser Valley to date. As mentioned later in the report, there have been relatively few deep exploratory wells drilled in the Fraser Valley. The additional three wells of this exploratory program will not dramatically alter the picture.

Despite these three wells, there is a great deal of potential in the Fraser Valley to explore, and it can be expected that those companies with permits, leases, or licences from the government, or private drilling agreements, will wish to carry out exploration. Figure 9 shows the petroleum and natural gas tenures in the Fraser Valley as of January 1991. These tenures are also described in Appendix I.

Petroleum geology literature contains many examples of basins which were thought originally to be nonproductive but later were found to contain petroleum. The producing area of Alberta, Saskatchewan and northeastern B.C., known as the Western Canada Sedimentary Basin, had hundreds of wells drilled before economic quantities of hydrocarbons were discovered in 1947 at Leduc, near Edmonton.

Discouraging exploration results from wells drilled on the United States side of the border, or on eastern Vancouver Island in the same geological formation may restrain interest in drilling in the Fraser Valley, but it is unlikely to cause it to cease. There is enough variation in the subsurface geology to warrant exploration in the area despite discouraging results nearby.

Virtually every delta geological formation similar to the Georgia Basin has produced hydrocarbons. These include the Beaufort Sea, the Niger Delta, the Mississippi/Gulf Basin, and the Manahakam Delta of Borneo. This does not mean that the Georgia Basin will produce oil or gas, but it does mean that there will be geologists and oil companies who will believe that it might. Only further unsuccessful exploration, perhaps in the order of thirty deep exploratory wells, can be expected to convince them that the possibility of a find is so slight as not to be worth further effort.

Finally it must be remembered that the use of gas as a fuel is increasing dramatically for both economic and environmental reasons, and a frontier area in terms of previous exploration, near major population centers is a very attractive combination to explore thoroughly.

Expected Developments in the Event Gas is Found in Commercial Quantities

Without information on subsurface reservoir characteristics, in particular information on porosity, permeability and reservoir thickness distribution, the effects of an economic gas discovery are speculative.

Gas Production Scenario

Assuming a natural gas deposit is found in a relatively homogeneous sandstone, one well per three square kilometres could reasonably be expected to exploit the reservoir. Thus a reservoir fifteen square kilometres in size would require approximately five wells for optimum recovery of the gas. Geophysical seismic mapping indicates the reservoir at each of the proposed sites to be a maximum of 15 square kilometres.

The area of land required for a producing well would be about 0.5 hectares (whereas the initial drill site would require one to

two hectares). Periodic maintenance of the wells sites would be required. Workover maintenance drill rigs would from time to time replace downhole equipment, primarily casing, which deteriorates due to corrosion and abrasion brought about by the production of gas and by unconsolidated reservoir sand. The schedule for such workover activity cannot be determined without exploratory drilling and a greater knowledge of the subsurface. As a rough guess, it may be every one to five years.

Processing of the extracted natural gas would require additional equipment such as separators and dehydrators at a centralized facility. The processing facility would occupy approximately 2 to 3 hectares. Connection of the producing wells to the processing facility would involve minimal pipeline construction in comparison with that done by B.C. Gas for its distribution system.

Fraser Valley Variables

The fluvial, nonmarine nature of sandstone deposition in the subsurface of the Fraser Valley may result in a somewhat heterogeneous reservoir. Thus porosity and permeability may be unevenly and erratically distributed. In addition subsurface faulting may fragment reservoir strata. Thus an ideal scenario of one gas well per three square kilometres may not materialize. Best Engineering Practice (BEP) may require closer spacing.

The geological and geophysical data available are limited. The Georgia Basin, in which the Fraser Valley is located, is essentially a frontier exploration region, with relatively little geological data. To accurately predict the density of wells in a prospective area would require additional geological and geophysical information.

The general assumption that natural gas and not oil will be present is based on gas produced from early wells,[1] and from recent geochemical analysis. However, in the very unlikely event that oil were to be encountered, the density of wells would be higher than for natural gas. Generally three wells per two square kilometres would be required to drain a reservoir. However, this figure may be higher or lower depending on reservoir characteristics of porosity and permeability distribution, and faulting patterns. The density of oil wells required if oil were discovered, as with gas wells, is speculative as data are lacking.

Petroleum Industry Reaction

If the exploratory program discovers natural gas in commercial quantities, the five other companies that currently hold rights to drill in the Fraser Valley will likely commence exploratory drilling. The commission is confident that they would be joined by others. Assuming government permission to drill is obtained, the pace of exploratory drilling would probably be swift over the next five years, particularly on the more than 800 properties where subsurface rights are privately owned and on which petroleum companies have already made arrangements to obtain drilling rights. No doubt petroleum company interest in areas where the Crown owns subsurface rights would increase, and requests to have more such areas opened for bidding could be expected. The prices that petroleum companies would be willing to pay for the right to drill, either to private subsurface owners or to the Crown, would also likely increase.

Economic Benefits

Another result of such a discovery would be cheaper natural gas for the B.C. Gas system, or at the least gas prices would increase at a slower rate than would otherwise be the case. How much cheaper or how much less the increase would depend on regulatory actions of the B.C. Utilities Commission, and on the financial arrangements between B.C. Gas and its partners in the consortium. This lower price in turn would lead to a greater use of the fuel in the Lower Mainland and

[1] Such as those which lit streetlamps in Steveston in the early 1900s.

Vancouver Island areas, leading to possible breakthroughs in the use of natural gas for vehicles, particularly fleet vehicles. The popularity of other energy sources would correspondingly decline in relative terms, with consequent adverse economic impacts on these industries.

The economic impact of lower gas prices with a better assurance of supply would also be important for industry, and would show up in a minor reduction in costs, fewer industrial operations being on interruptable supply, and fewer companies being tempted to move to Alberta or some other jurisdiction with low energy costs and assured supply.

The interest of B.C. Gas in underground natural gas storage could be expected to decline, at least until the extent of the potential Fraser Valley production was established. If the discovered field were extensive, or if more were found, B.C. Gas might shelve underground gas storage proposals until the gas in the formation (or formations) was exploited and the field partially empty, at which time the field itself might well be used by B.C. Gas to provide winter or peak load storage. Fraser Valley production, in other words, could substitute for a gas storage facility.

Westcoast Energy would delay looping and other expansion plans for the transmission system until the effect of the local Fraser Valley supply was accounted for by demand increases, or by export increases.

Regardless of whether the gas was found on Crown lands, provincial revenues would increase, leading to a general improvement in public services to the citizens of the province at lower personal tax rates, identical to that currently obtained from present revenues from the industry in northeastern B.C. If the find were on Crown lands, this effect would be greater. If the find or finds were on privately owned subsurface properties, a number of Fraser Valley landowners could expect very substantial revenues. The total new wealth would be considerable; a 100 Bcf reservoir could be expected to provide 200 million dollars of new wealth to all parties.

Finally, if past experience elsewhere provides a guide, surface land values would likely increase. Further, the industry will likely pay more than its share of local taxes, and in addition make substantial voluntary contributions to local facilities in an effort to create acceptance of its presence and to reduce resentment of the impact of its operations. This will also increase land values. Land values are discussed in more detail in Chapter 9.

Environmental Benefits

The benefits of a commercial find of gas in the Fraser Valley are considerable. First, cheaper gas can be expected, with greater security of supply. This will result in greater use of the fuel, and thus better air quality in the Fraser Valley. In addition, there will be less need for gathering systems in the northeast, and for expansion of the transmission system from there to the Lower Mainland. This will have substantial savings in terms of pipe, equipment and machinery manufacture, the consumption of fuel for transmission purposes, and less or at least delayed impact of exploration in the northeast, particularly for road systems. Conservation of natural gas in the northeast may be improved, as the fluctuating demand between winter and summer may be reduced. This advantage is not as clear with production as with storage.

Similarly, the need for environmentally expensive backup systems for institutions that cannot afford to be without power (hospitals and universities, for example) will be reduced. Such institutions will also be able to expand environmentally friendly cogeneration, based on natural gas as a fuel. Little has been done in this regard in British Columbia to date.

The impact of production of natural gas on agricultural, forested and other non-urban

land in the Fraser Valley will be mildly positive in the areas adjacent to the facilities. This impact will probably be less in the case of production than in the case of storage.

Environmental Costs

The major environmental cost associated with production of gas in the Fraser Valley is the alienation of approximately 6 hectares of land for the production system and the well heads. As explained in Chapter 7 of this report on agriculture and wildlife, against this must be offset the overall impact of the industry on land adjacent to its facilities, which will likely be to reduce land alienation for subdivision and urban uses, and thus, in an environmental sense, be positive. Another cost, which (apart from well maintenance activity) is temporary, is the aesthetic impact of the drilling. Aesthetic concerns are dealt with in a separate chapter.

Expected Developments if a Formation Suitable for Gas Storage is Found

If an exploratory program does not encounter reserves of natural gas, the target formation may provide possibilities of gas storage.

Were this to be the case there would probably be requests to carry out further drilling to test out the formation. Assuming that further drilling is allowed and takes place (or, alternatively, assuming that the initial test hole provides adequate data), assuming that the information on the subsurface geology from the drilling enables B.C. Gas to do the detailed technical and economic planning necessary to complete their assessment of the project, and assuming further that these calculations come up with positive economic projections, an application for the development of a natural gas storage facility could be expected to be made to the B.C. Utilities Commission.

A second result of a dry formation find would be a higher level of continued interest in exploration in the Fraser Valley than would be the case were the results entirely negative, as in the first scenario described above.

The issue of undergound natural gas storage, and the benefits of increased natural gas usage, is discussed extensively in the next chapter. The following, however, gives an indication of the type of development that would occur with an underground gas storage facility.

Gas Storage Scenario

Well density and distribution

Commission staff visited a number of underground gas storage facilities in Canada and abroad. One clear conclusion is that there is no typical storage facility in terms of well density and distribution. However the number of wells drilled for operation of a storage field was always in excess of what would have been required for a gas production facility.

Well density and distribution are dependent on geological parameters and on the type of storage anticipated (i.e., aquifer, depleted oil or gas field, salt cavern, or mined cavern). The Jackson Prairie sandstone aquifer storage facility (Washington State) has 77 wells — roughly 5 per square kilometre. In contrast the Aitken Creek storage facility near Fort St. John B.C., has 13 wells on a spacing of 1 per square kilometre.

Numerous storage facilities, such as Montebello storage facilty near Los Angeles (Plate 9) and Chemery storage facility in France (Plate 12), utilize directional drilling technology to reduce the number of surface locations by 50% - 90%.

Compression facilities

Generally compressor stations occupy an area of 2 to 4 hectares. The Fraser Valley

already has a major compression facility at Westcoast Energy's #9 plant. The main physical impact of compressor stations is noise generated during the injection/ withdrawal cycle.

Modern storage facilities, such as Gournay sur Aronde in France, have integrated facilities to blend as much as possible with the surrounding countryside. An extensive program of consultation was initiated by Gaz de France, the operator of the Gournay sur Aronde facility. The Montebello storage facility in Los Angeles has painted its equipment (compressors, dehydrators, etc.), a light brown colour to blend into the surrounding hillside.

Unlike a typical gas production facility which can have an operating life of up to 30 years, a gas storage facility can theoretically operate indefinitely.

Economic Benefits

The potential benefits of underground natural gas storage are considerable. The commission has concluded that B.C. Gas has been conservative in estimating the benefits to its customers of a natural gas storage facility in the Fraser Valley at approximately $30 million per year. By reason of the regulated nature of the utility, this saving will be passed on in lower costs to both residential and industrial consumers. It has concluded further that the possible benefits to other parties, including producers of gas in northeastern B.C., are at least as great as to the customers of B.C. Gas. The commission further concludes that the benefits to the province in terms of better utilization of provincial resources and greater opportunities to devote the money saved to other social purposes to be substantial.

Unfortunately there can be no reliable analysis of the overall economic benefit without information on the geological formations below the test well sites. This can only be obtained by way of drilling. A cost benefit study is not possible at this time.

Economic Costs

The economic disadvantages of storage would come from a miscalculation on the part of B.C. Gas of costs in developing the facility, or by reason of the costs that would be incurred if the facility was partially developed and which later was found to be usable, as in the case of the Russell development in Ontario. Were the facility to leak gas, drilling to a capture zone to recover the gas would result in expenditures. In the highly unlikely event that water wells were affected before the leaks were intercepted and the escaped gas recaptured, there would be further expenditures for well replacement. Were such problems encountered, the costs of remedial action would be highly unlikely to total more than four months of the economic benefits of the project as currently calculated.

Environmental Benefits

From the environmental point of view, the advantages of natural gas storage in the Fraser Valley are substantial.

First, the establishment of a natural gas storage facility in the Fraser Valley will have the effect of reducing natural gas prices, thus increasing the use of that fuel and decreasing the use of other fuels with greater environmental (particularly air quality) impact.

Second, the added security offered by an underground natural gas storage facility will dampen the effects of any break in the Westcoast transmission pipeline, reduce the backup or alternative expenditures required by large institutional customers, and make them more receptive to conversion to gas, and more receptive to local or small scale co-generation of power and heat.

Third, the use of an underground storage facility reduces the requirement, or delays singnificantly, the expansion of the Westcoast pipeline system from the northeast of B.C. to the Lower Mainland. This results in important savings of many hundreds of millions of dollars worth of

steel, machinery and other products, the creation and deployment of which would have substantial environmental costs.

Fourth, the creation of an underground gas storage facility can be expected to have less impact on land than would be the case of an expansion of the Westcoast system and the gathering system of the northeast.

Finally the expansion of storage facilities will result in more even extraction rates for gas in the northeastern part of the province; thus extraction rates can be more efficient, and conservation of the resource can be enhanced.

Air quality is the environmental area where the increased use of natural gas would, literally, be most visible to the residents of the Lower Mainland. The area of the province which would most benefit from a greater use of natural gas is the Fraser Valley, which has a serious and increasing air quality problem of the Los Angeles type. Greater use of natural gas would improve the approximately 150 days of the year in the Chilliwack area where ozone is above the desirable Canadian standard (50 parts per billion), and the four or more days of the year where it may rise above the acceptable Canadian standard (80 parts per billion). The situation at Port Coquitlam is worse. With continued Lower Mainland growth, and without substantial conversion to natural gas or some other less polluting fuel for vehicles (which are responsible for 80% of air pollution in the region), the Lower Mainland population and the Fraser Valley population in particular can be expected to suffer from deteriorating air quality.

The commission has concluded that the air quality improvement objectives for the decade of the GVRD Air Management Plan cannot be achieved without substantial conversion, particularly of vehicles, to natural gas, and the most likely means of achieving this conversion is through the price improvements that may follow the exploitation of a natural gas discovery in the Lower Mainland, or the discovery and exploitation of a storage formation.

Environmental Costs

There are few environmental costs of such a facility, other than the small amount of land (2-4 ha) that a compressor station would occupy, and the expected 5 metre by 8 metre areas surrounding 15 to 80 observation and injection/withdrawal wells, assuming that these are done with vertical, rather than deviated, drilling, and are thus not at the site of the compressor station. In addition there are aesthetic considerations, such as noise, smell, traffic and inconvenience in particular during the period in which the facility is being established. Some amenity costs are associated with running the facility; noise, for example, cannot be reduced to zero, although it can be reduced to low background levels.

There are some environmental risks, which are potential environmental costs. Groundwater contamination from natural gas escaping from an underground storage facility was a major matter of concern at the public hearings, and was carefully studied by the commission, which has concluded that while the risk exists, it is very slight.

Natural gas migrations in other storage facilities where, through overpressuring or some other reason, the caprock has released gas, suggests that in the highly unlikely event of an appreciable leak from a modern storage facility, the escaping gas, being lighter than air, will follow a relatively narrow path to the surface, and affect very few wells of an aquifer as a result. Further, the method of tracing and capturing escaped gas from storage facilities is well developed; thus the possibility of such a problem existing in the aquifer for more than a short time is not high. In addition natural gas is only slightly water soluble, thus affected groundwater can be expected to purge itself of the gas over time. Finally water fully saturated with natural gas is not harmful to human health. These issues are discussed in more detail in later chapters.

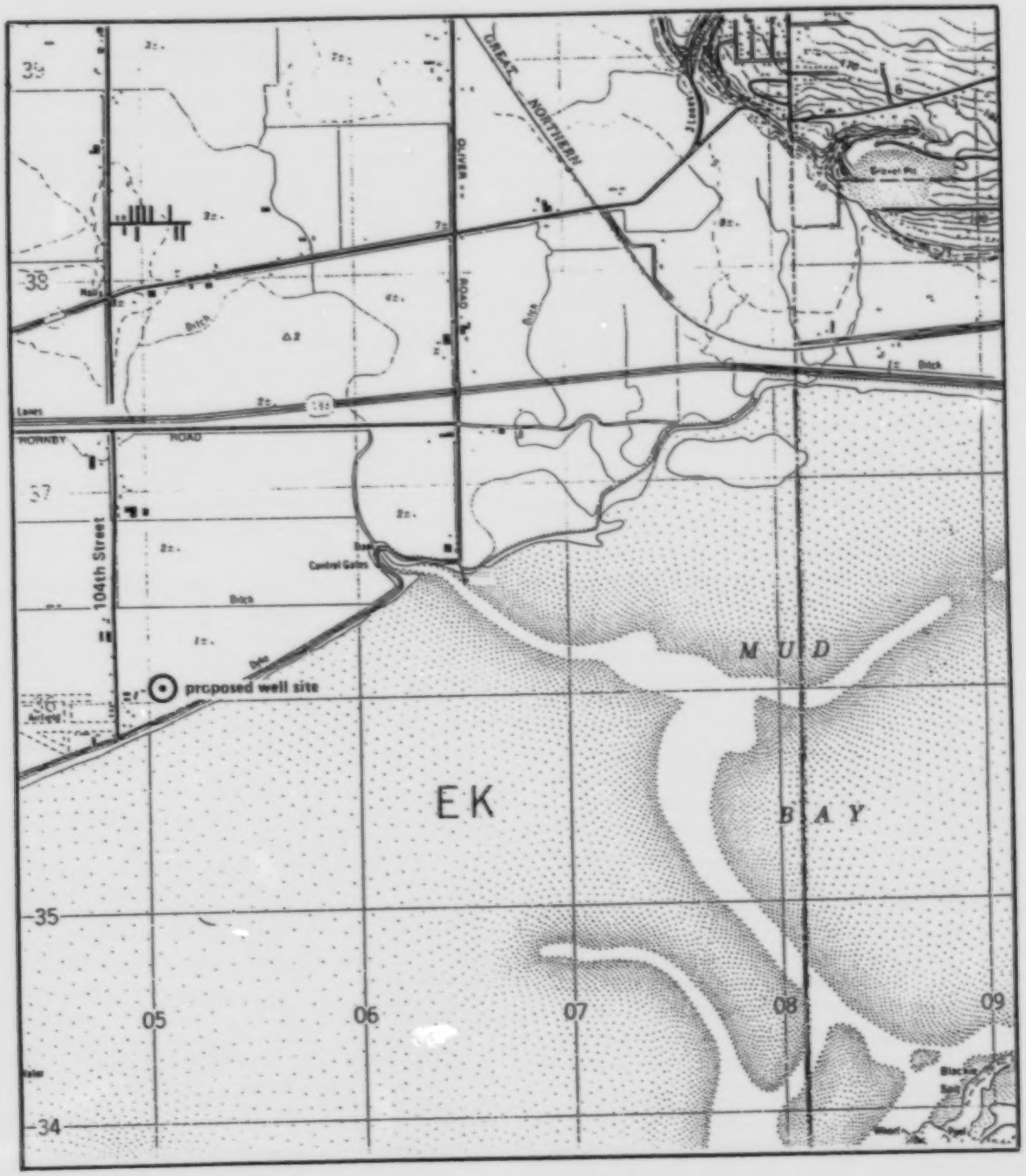


FIGURE 3 — Boundary Bay Proposed Drilling Location, Delta.

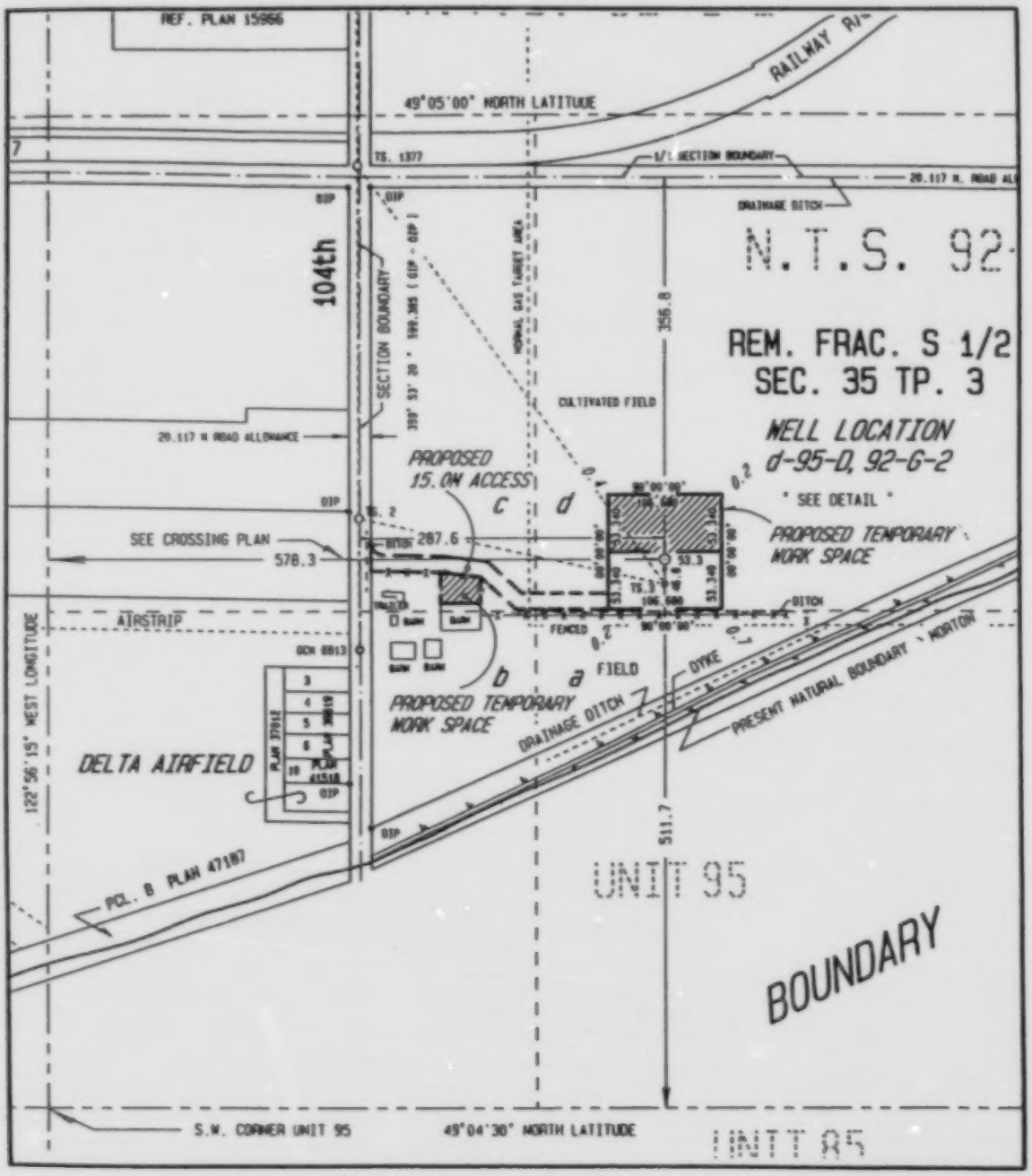


FIGURE 4 — Boundary Bay Proposed Site Layout, Delta.

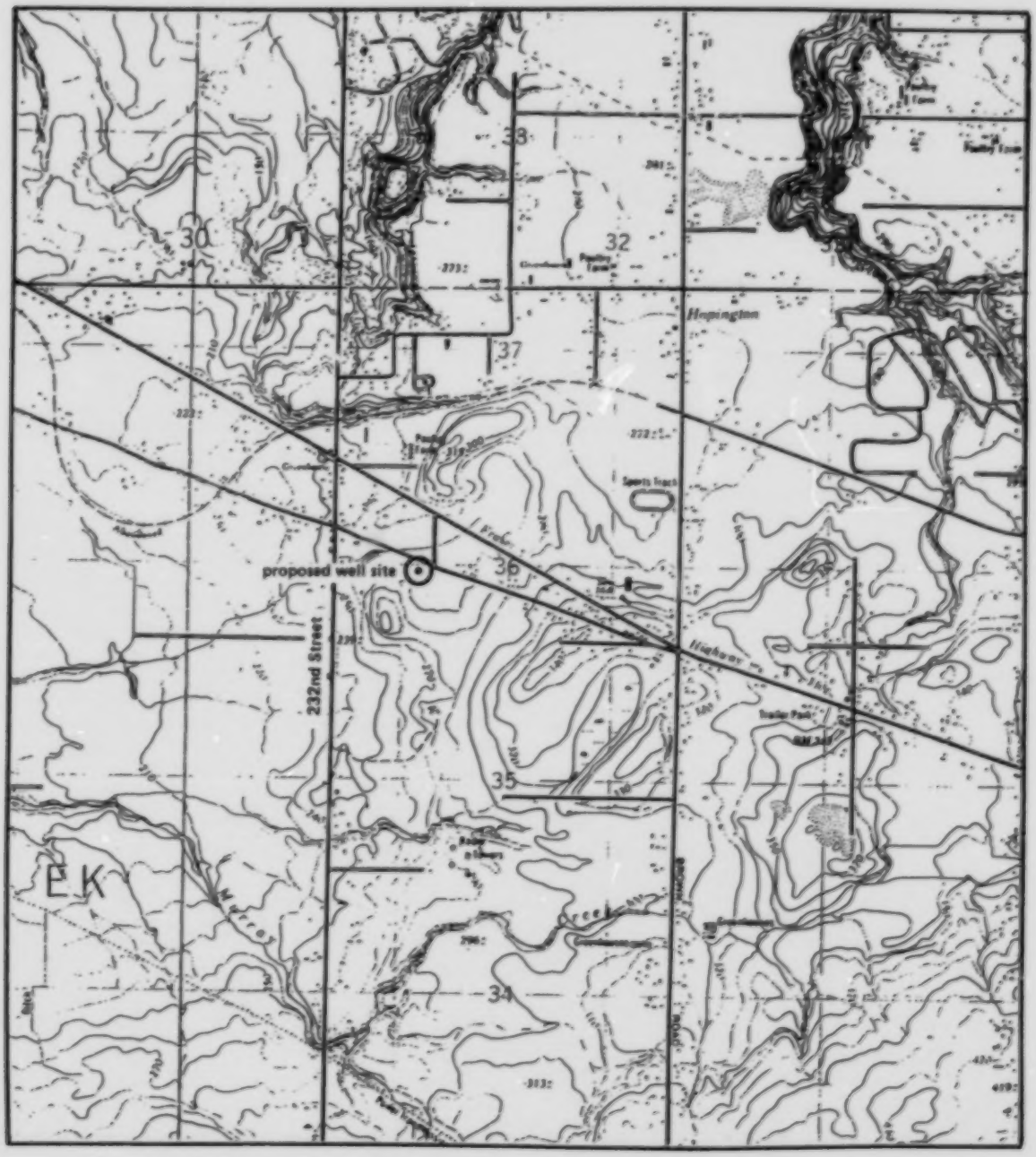


FIGURE 5 — Murray Creek Proposed Drilling Location, Langley.

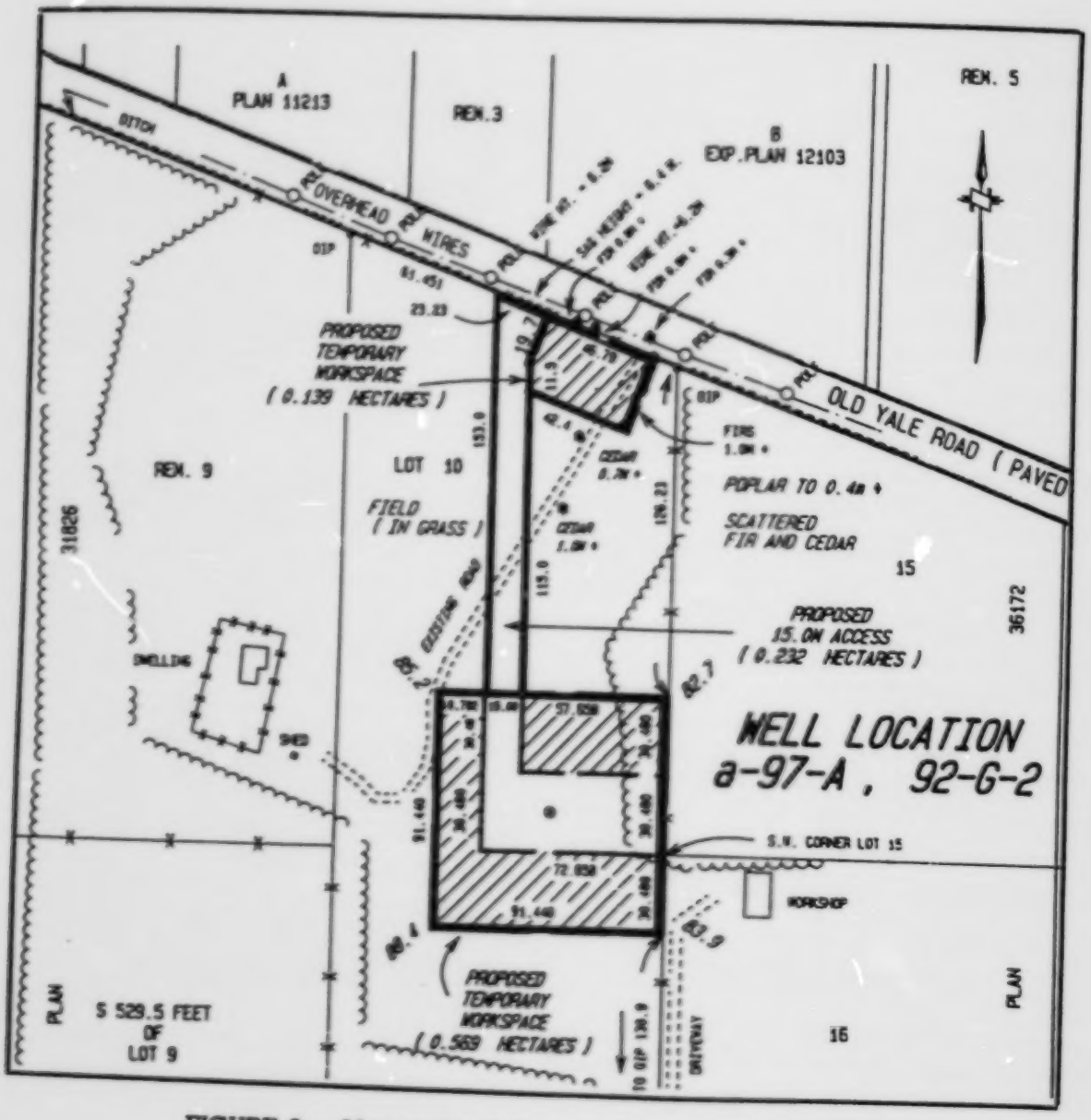


FIGURE 6 — Murray Creek Proposed Site Layout, Langley.

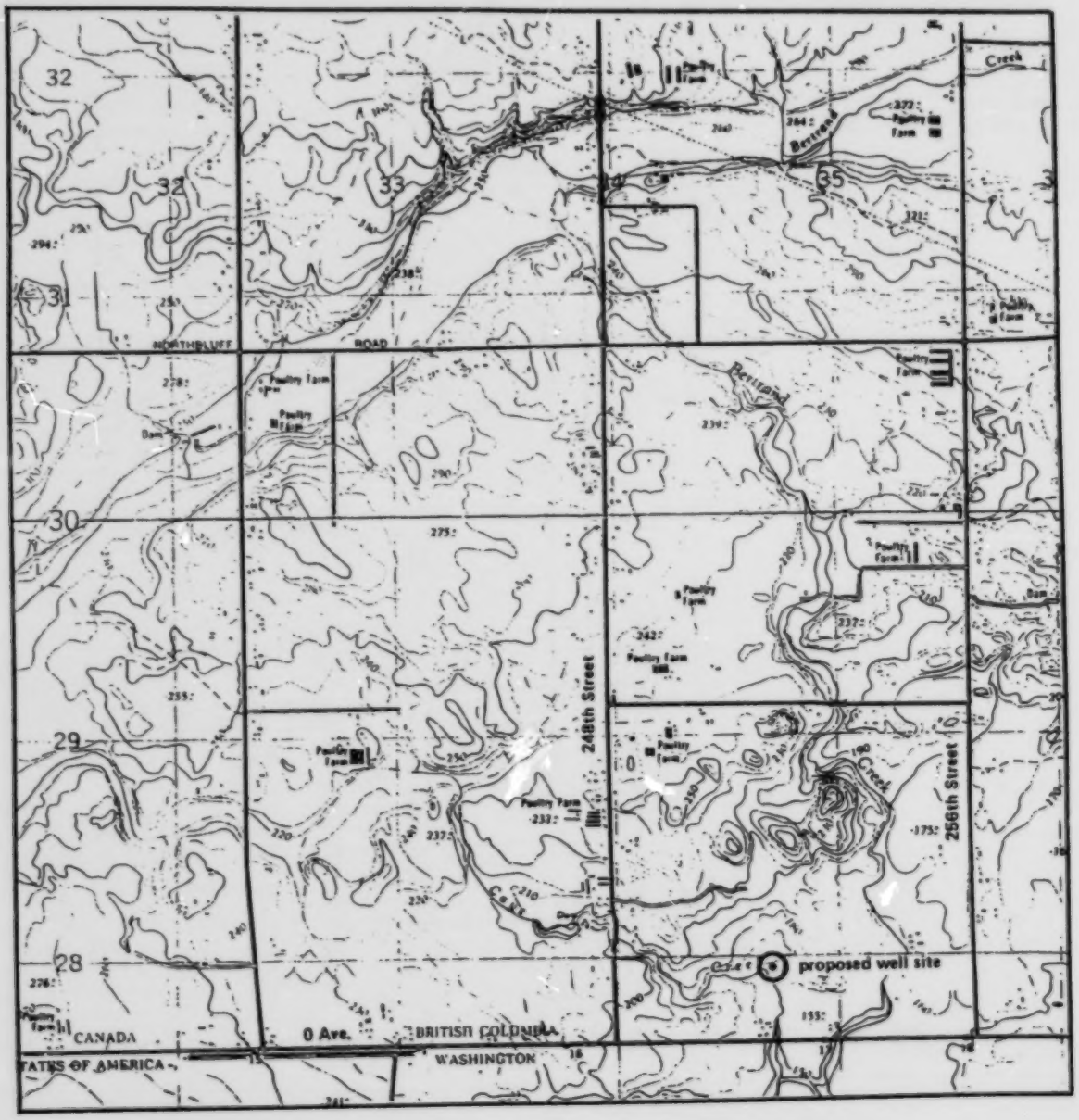


FIGURE 7 — Campbell River Proposed Drilling Location, Langley.

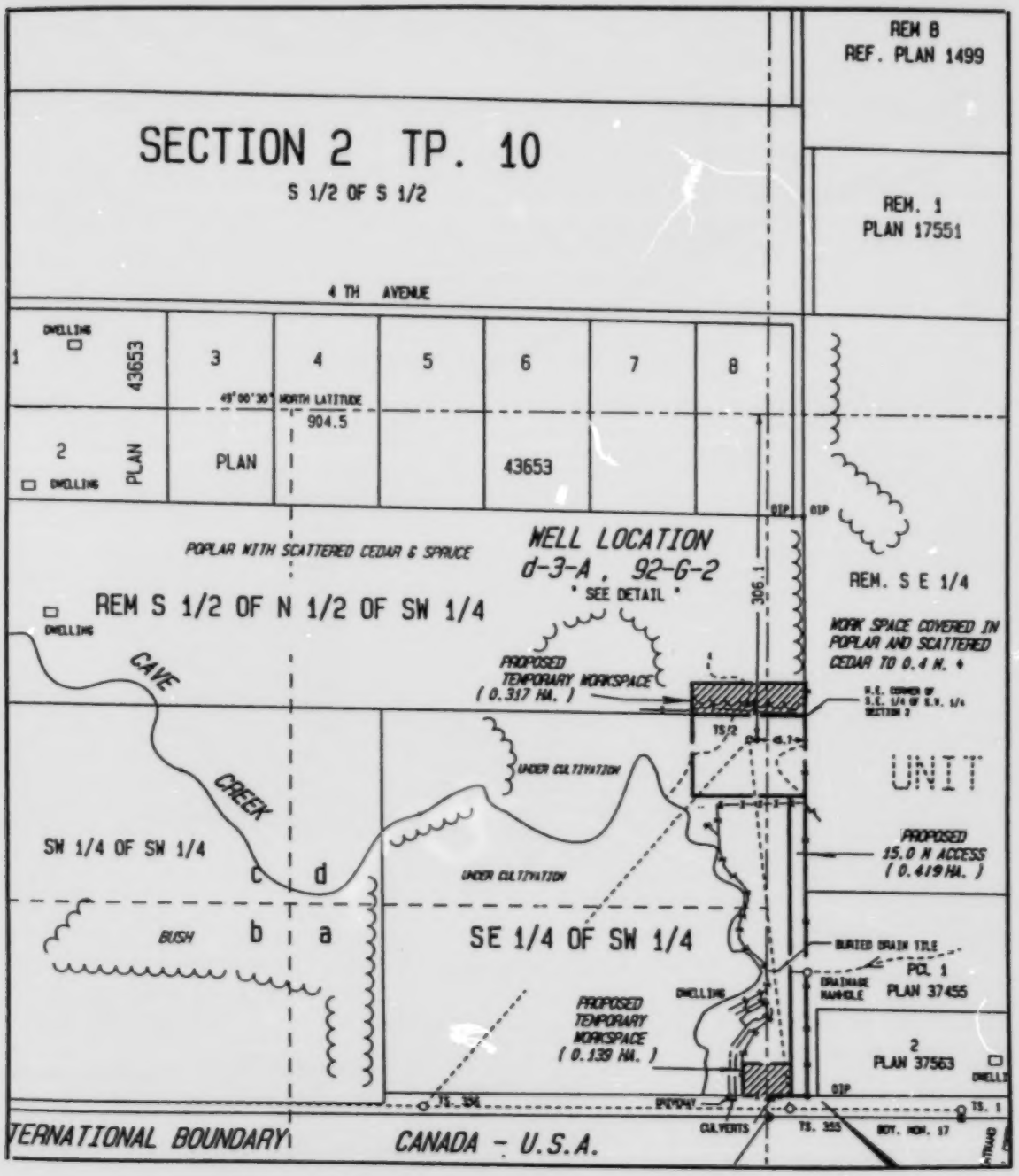
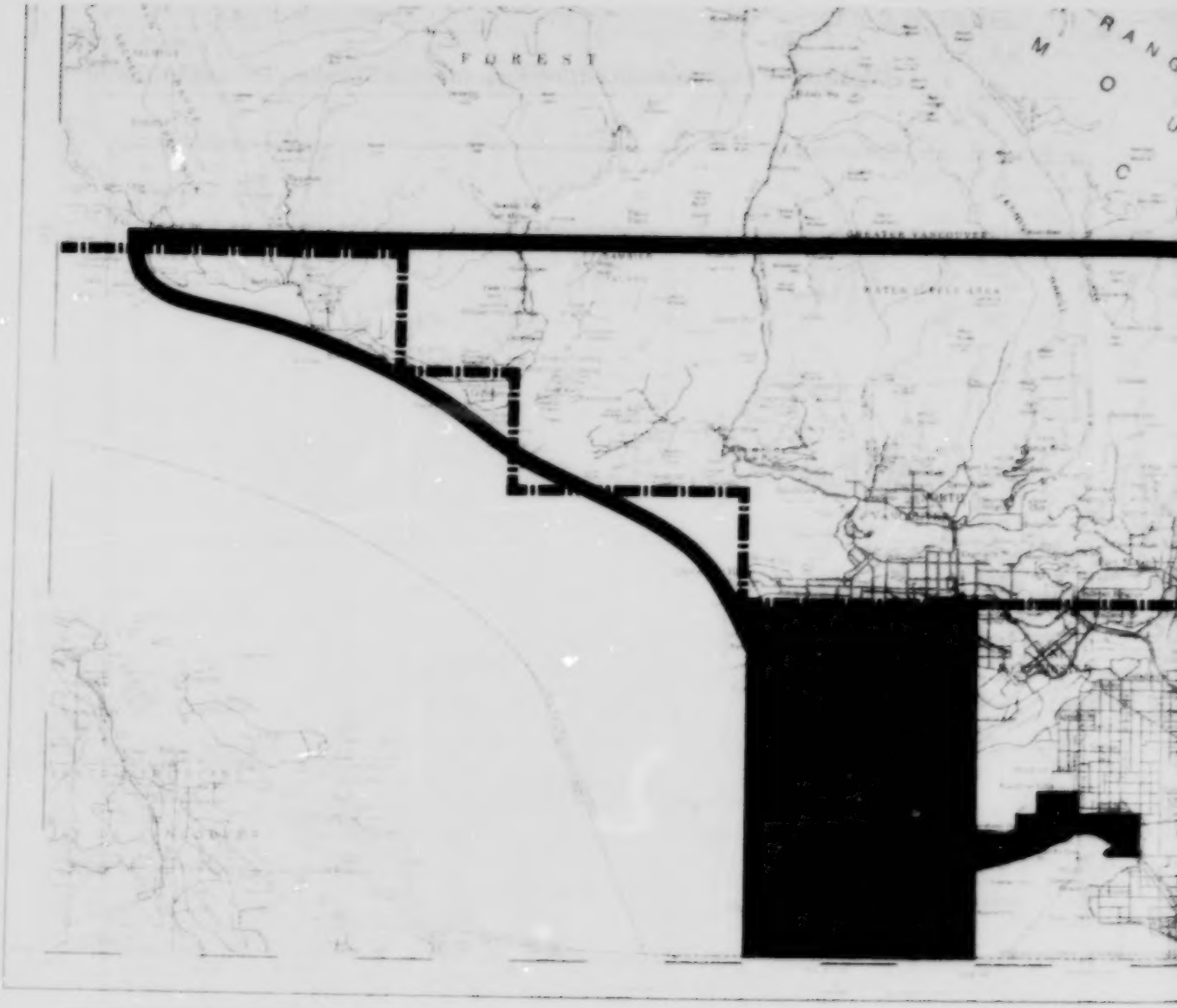
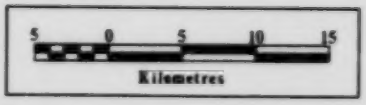


FIGURE 8 — Campbell River Proposed Site Layout, Langley.





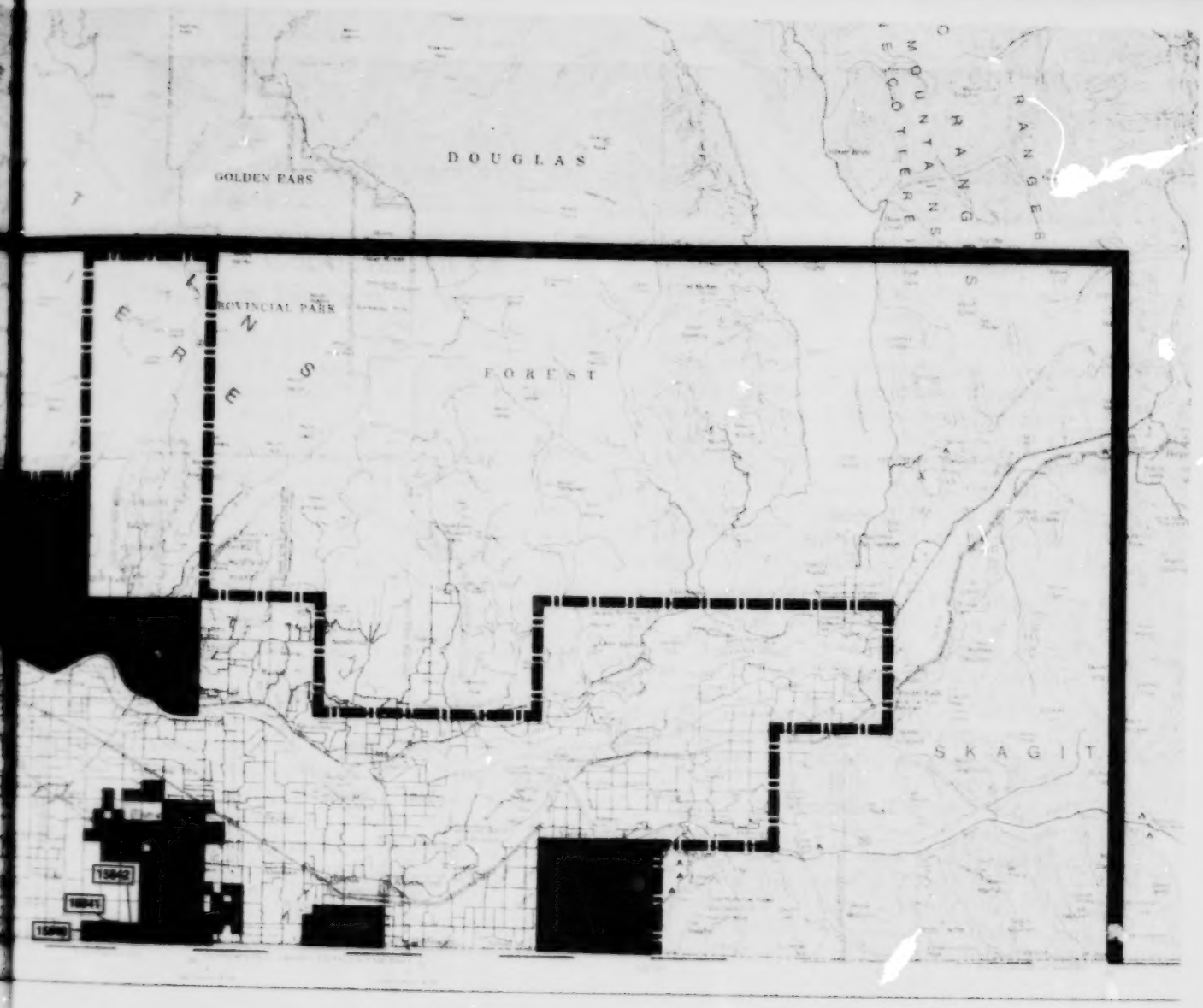
LEGEND

- Area of Inquiry boundary
- Crown Reserve boundary
- PERMIT
- DRILLING LICENCE
- LEASE

FRASER VALLEY PETROLEUM AND NATURAL GAS TENURE MAP

FIGURE 9

SOURCE: Ministry of Energy, Mines and Petroleum Resources.



TENURE SUMMARY

Jan. 1991

Title No.	Type	Title Holder	Hectares	Issue Date
802	Permit(Class D)	Dynamic Oil Limited	21,988	57 10 23
3133	Permit(Class A)	Epic Resources B.C. Ltd.	6,910	87 04 08
3134	Permit(Class A)	Epic Resources B.C. Ltd.	4,780	87 04 08
3157	Permit(Class A)	McLean Oil & Gas Limited	7,607	89 03 01
448	Drilling Licence	Conoco Canada Limited	2,211	89 10 25
449	Drilling Licence	B.C. Gas, CanHunt, Optima, Epic	2,612	89 10 25
450	Drilling Licence	Conoco Canada Limited	3,310	89 10 25
451	Drilling Licence	Canadian Coastal Resources Ltd.	2,007	89 10 25
15837	Lease	Conoco Canada Limited	264	89 10 25
15838	Lease	Conoco Canada Limited	441	89 10 25
15839	Lease	Conoco Canada Limited	476	89 10 25
15840	Lease	Conoco Canada Limited	259	89 10 25
15841	Lease	Conoco Canada Limited	259	89 10 25
15842	Lease	Conoco Canada Limited	259	89 10 25

NOTE: SOME TENURES HAVE EXCLUDED AREAS WITHIN THEIR BOUNDARIES

Role of Commission on Storage Issue

The issue of gas storage has been a major concern of the commission. A clarification of the commission's role in this regard may be useful.

Many of those who have commented at public meetings and in the press on the possibility of underground natural gas storage in the Fraser Valley erroneously have assumed that this commission has been authorized to make recommendations on whether the provincial government should approve underground natural gas storage. In fact, this commission has not been instructed to give its opinion on whether gas storage should take place in the Fraser Valley; indeed, at the present time there is no application for a natural gas underground storage facility before the government. Given the present state of knowledge of the Fraser Valley's geology, this is as it should be. At the present time there is not the knowledge of potential underground formations and structures in the area that would permit an informed decision in favour of or against underground natural gas storage.

Instead there is a proposal to carry out exploratory drilling, one of the objects of which is to determine whether there are natural gas deposits or favourable geological conditions for an underground natural gas storage facility. Any decision on whether there should be storage thus must await government approval (if it is given) to carry out the exploratory drilling program. Then and only then, assuming first that the exploratory program results in favourable data regarding geological structures, and second that it does not result in the find of an existing gas field, could it be expected that the company interested in underground natural gas storage, B.C. Gas, would present a proposal to the government for approval. Then and only then would the site-specific proposal be analyzed and a decision made by the provincial government on whether it should proceed or not. Mr. Patrick Lloyd, the Senior Vice President of B.C. Gas, who testified at the commission's technical hearings, made the point at the outset of his testimony. He said:

> *B.C. Gas' application for underground storage is still a few years, and a number of regulatory applications, including at least one more public hearing, into the future.*[1]

The process for such approval was discussed at the technical hearings by (among others) Ms. Joan Hesketh of the British Columbia Ministry of Energy Mines and Petroleum Resources, at pages 67 and 68 of the transcript, and was outlined in the Ministry's presentation to the commission[2] at page 26 under the heading "British Columbia's Underground Storage Policy". It would involve a hearing by an independent hearing panel appointed by the British Columbia Utilities Commission. The earliest such public hearings might take place is 1992; far more likely is 1993.[3]

The commission's role is not to anticipate this possible future process, but to consider the issue of underground natural gas storage in the context of expected or possible developments from the exploration proposals under consideration. It is not for this commission to give an opinion on whether or not underground natural gas storage should take place. Its task is to outline some of the potential costs and benefits that underground

[1] Transcript, page 1023.

[2] Exhibit T-2 of the commission's list of exhibits.

[3] Transcript, pages 1026 and 1027.

storage might have, and thus to assist the government in determining what are the potential benefits and costs of exploratory drilling.

For example, if the potential benefits of underground natural gas storage are non-existent or negative, then underground natural gas storage is not a factor that should be given weight when determining whether exploratory drilling should proceed. Conversely, if underground natural gas storage potentially has substantial benefits and few adverse consequences, then the possibility of underground natural gas storage would be a positive factor in determining whether exploratory drilling should take place.

In the paragraphs above the possibility of a find of a natural gas field has been mentioned as a factor that might result in B.C. Gas not proceeding with an application for a storage facility. This requires a brief explanation.

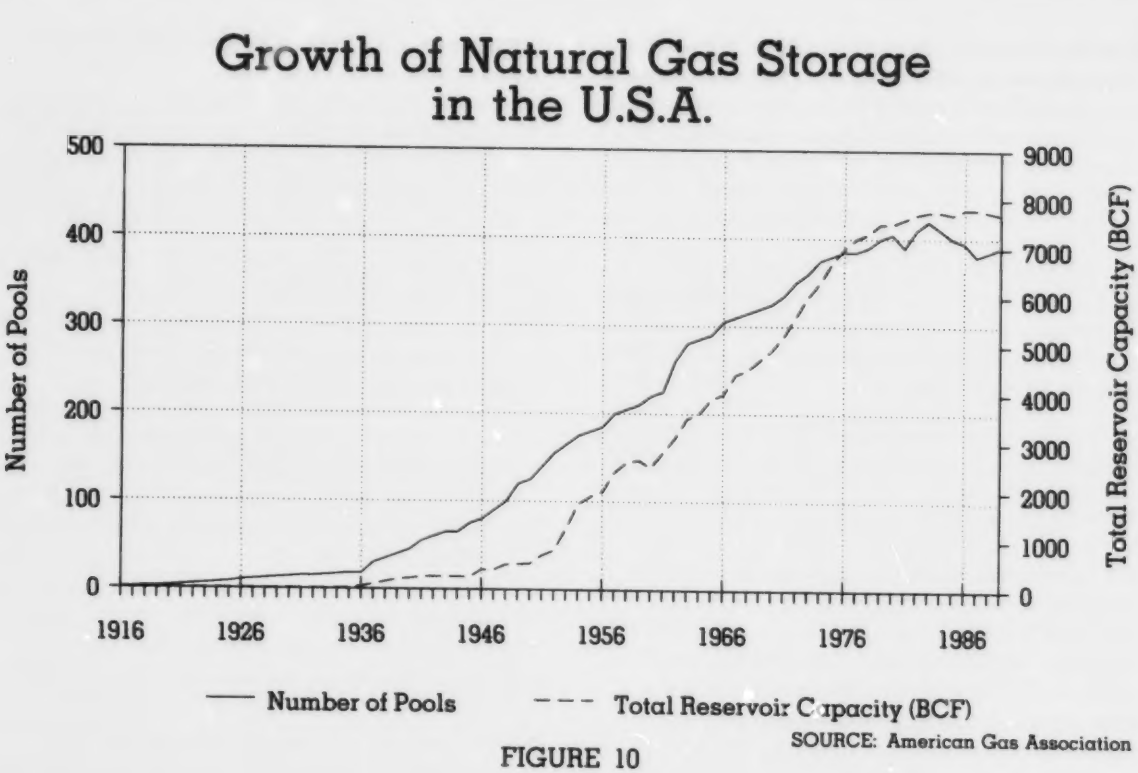
The storage of natural gas often takes place in depleted gas or oil fields rather than in geological structures that have not produced hydrocarbons. Storage in a depleted field is in fact far more common than storage in an aquifer formation that has not previously been a producing field. This is an important fact to bear in mind when exploratory drilling is under consideration. If exploratory drilling is approved, it may be that it will lead to a substantial gas find in the Fraser Valley, and it may be that this gas find will be easily and economically exploitable. The consortium's three companies are spending millions of dollars on the assumption of that being the case. If the consortium is correct and gas is found, much of the rationale for storage advanced at the commission hearings might alter — in other words, the use of the newly discovered Fraser Valley gas might make storage unnecessary or less valuable, as substantial winter peak load gas supplies might be available from the new field. There are, of course, many variables, and it should not be assumed that if gas is found, underground natural gas storage inevitably becomes of no interest to B.C. Gas. It is not an either/or situation, but one involving a complex matrix of technical, economic and environmental factors.

Another factor of note is that a find of gas in the Fraser Valley may result in storage opportunities in the future. After some years of exploitation, when the field becomes partially depleted, storage might be possible in the existing formation that until then has been producing gas. Indeed, even well before withdrawals of gas depleted the field, it might be feasible to inject gas from the Peace River in summer into the formation, using the existing gas in the formation for cushion purposes, and to withdraw gas in winter for the Lower Mainland/Vancouver Island consumers.

All this is speculation. We are a long way from knowing whether such a gas deposit exists in the Fraser Valley, and even further from knowing whether it is commercially exploitable and what its volume and flow characteristics might be. What we can be certain of is that the discovery of gas in commercial quantities in the Fraser Valley will affect any gas storage proposal. Much of the discussion before the commission about gas storage in the Fraser Valley overlooked what the effect a discovery of a gas field might have on the existing situation, and it is important to point out the linkage that exists.

History of Underground Natural Gas Storage

The first example of pumping natural gas underground for storage purposes took place in Welland County, Ontario, in 1915, and the first in the United States took place in the following year near Buffalo, New York. By 1937 there were 22 underground natural gas storage facilities in the United States, with a total capacity of more than 100 billion cubic feet.



SOURCE: American Gas Association

FIGURE 10

In 1950 the number of underground natural gas storage facilities in the United States had climbed to 125, and the amount of storage had increased to 774 billion cubic feet. In 1972 this had increased to 348 fields, in 26 states, with a capacity of 6 trillion cubic feet. Today, there are some 430 underground gas storage facilities in the United States (Figure 10), some 26 in Canada, 14 in France, 32 in Germany (24 in the former West Germany, and 8 in the former East Germany), 9 in Italy, and another 40 throughout the world. Many more are currently under construction, particularly in Western Europe. Germany, for example, has ten facilities being developed, while France is expected to bring two new storage facilities on stream in the next decade. The total capacity of these storage facilities is about ten trillion cubic feet.[4]

Rationale for Underground Natural Gas Storage

The purpose of this section is to outline the rationale for natural gas storage, and to indicate why it has become such a common feature of natural gas distribution systems throughout the world.

Security

There are a number of reasons for this interest in gas storage, and in the development of the practice that has been outlined above. Security of supply is an important consideration. France and Germany for example, have little natural gas production of their own. France imports some 90% of its requirements, while German domestic supplies provide less than 17% of domestic consumption.

[4] One reason for the dramatic increase in European interest in storage is the need to effectively utilize Soviet gas supplies. The Soviet Union has almost 40% of the world's known natural gas reserves, more than those of the Middle East, perhaps twelve to fifteen times those of Canada. Gas storage is a critical component of the integration of these distant Soviet supplies to the economies of Europe.

Both countries rely on the USSR for approximately 30% of their domestic gas supplies. This supply both from a technical and political point of view, cannot be considered reliable. Further, France and Italy both rely on North Africa for approximately one third of their requirements. Again, the source cannot be counted on, and the use of cryogenic tankers for delivery in the case of France (Italy relies on a pipeline below the Mediterranean Sea) poses further technical concerns.

Security of supply is also of concern to North America. Outages of electricity are well known in B.C., despite high expenditures of time, energy and money by B.C. Hydro to reduce their frequency and their duration. By reason of extreme weather conditions and through no fault of the utility company, power outages were frequent in November and December of 1990 and January of 1991.

The situation is much the same for gas. In 1980 the pipeline transporting Alberta gas to Ontario was out of service for four days.[5] Although existing storage and alternative United States deliveries averted serious disruption, the event underscored the importance of the existing storage facilities to the southern Ontario gas distribution system. Other pipeline and compressor stations elsewhere in North America have experienced similar interruptions in service. No similar interruption of supply has occurred on the Westcoast Energy system in the thirty years of its operation from the Peace River to the Lower Mainland area. The company has good reason to be proud of its record in this regard. It should be noted, however, that the possibility of a landslide or other disruption along the pipeline route is high, and must be taken into account. B.C. Gas witnesses, particularly Mr. John Thrasher, Manager of Gas Supply Planning, also expressed concern on this point, concern which was reflected in the testimony of the British Columbia government witnesses. He said at page 1047 of the transcript:

> *. . . We're living with these insecurities today. They're the concerns about Westcoast having a disruption of their system as a result of a pipeline break, a compressor failure, a processing plant problem, or possibly freeze-offs at the wellhead with producers.*
>
> *. . . They have not occurred at peak winter periods when we were relying on the full Westcoast capacity. But there is some concern on our part that we have very little protection against something like that happening. We have the LNG [Liquified Natural Gas] plant, but it only supports us for four days in the winter.*
>
> *We would like to have the added protection of having a large storage facility in our own backyard that would help us weather out, ride out, a disruption on the Westcoast system.*

If the gas transmission system is interrupted, perhaps by landslides similar to those that cut all three highways between the Interior and the Lower Mainland (the Hope-Princeton, the Trans-Canada, and the Coquihalla) on the Remembrance Day weekend of 1990, the interruption can be expected to be in the winter when rock and soil stability is affected by heavy rains or snow, and when gas demand is high. The risk of such a slide in the eastern Fraser Valley is high. Motorists on the Hope-Princeton highway can view the results of the 1967 Hope slide, while those on the Trans-Canada highway can see evidence of other early landslides just past Hope. Landslide effects near the Minter Gardens and the Flintstones Park can also be observed. Mount Cheam has high landslide risks. The possibility of the transportation and energy corridors linking the Lower Mainland with the Interior being cut by landslides must be taken very seriously.[6]

[5] Transcript, Mr. Ivan Cuthill, of Consumers Gas, pages 1329-31.

[6] The commission acknowledges with thanks the information on landslides in the eastern Fraser Valley provided by Dr. Wayne Savigny of the Geological Sciences Department of the University of British Columbia.

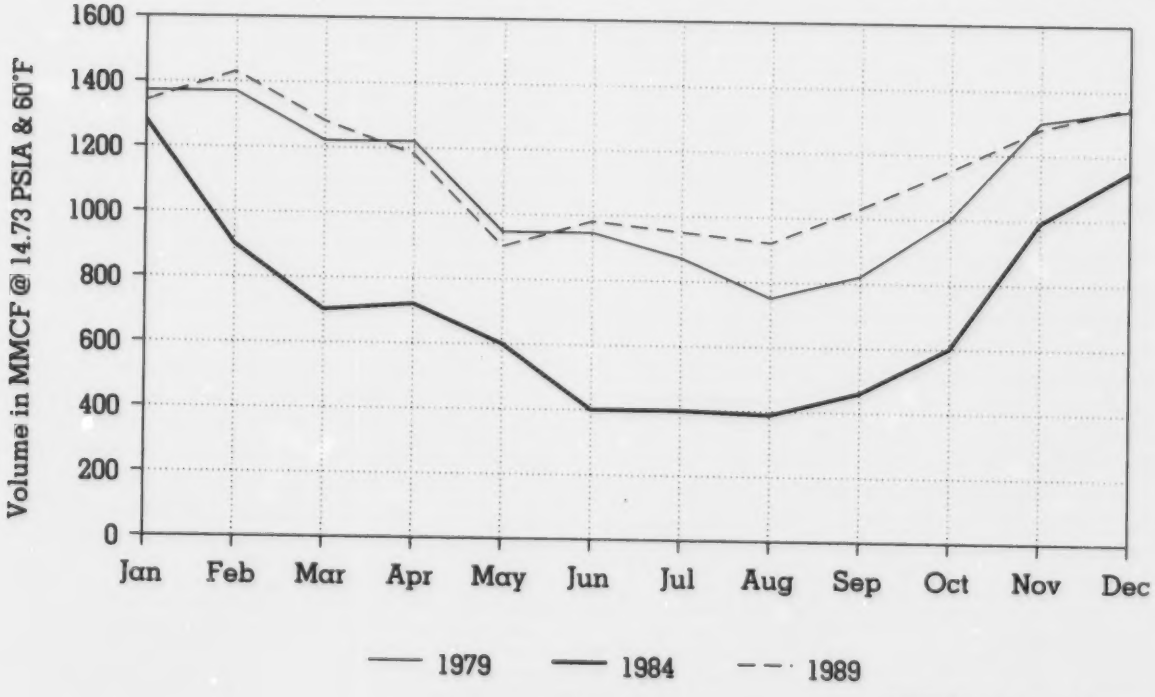
Given the importance of natural gas to the Lower Mainland, and the pattern of pipelines in the area, a pipeline break cannot be taken care of by bringing gas in from elsewhere. We do not have the flexibility that existed in Southern Ontario in 1980 when the Trans-Canada line was interrupted. Further, British Columbia does not have another fuel which could be used as an alternative to gas. A landslide in the eastern Fraser Valley would likely affect one of the B.C. Hydro transmission lines as well, and thus reduce electrical supply to the Lower Mainland. Even if it did not, under the winter and bad weather circumstances envisaged, the B.C. Hydro system would probably be operating at capacity. Spare electricity supply likely would not be available. Finally, the expected efforts of gas customers to use electricity as a substitute for their lost gas supply would no doubt severely increase loads, and adversely impact the B.C. Hydro system.

Seasonal Load Factors

Security of supply is not by any means the only or even the primary advantage to the industry of natural gas storage systems. In winter, space heating of homes, offices, and commercial and industrial buildings leads to extensive demands on gas delivery systems, demands that essentially terminate with the arrival of warmer weather in the spring. The result is dramatic fluctuations in demand.

Gas demand in July in the Lower Mainland can be expected to be half of

Average Monthly Total Receipts to Westcoast Energy's Gas System in Selected Years



SOURCE: Westcoast Energy

FIGURE 11

the January demand. Except for summer demands related to gas thermal generation of electricity for air conditioners, most of the other users of the Peace River to California gas pipeline system have similar space heating induced fluctuations in demand.[7]

Thus the seasonal fluctuations within the system tend to be cumulative. All utilities purchasing gas from northeastern British Columbia, using the Westcoast system for delivery, can be expected to need more gas at the same time. The result is winter periods of high demand on the delivery system, and summer periods of low demand. The pattern of these seasonal variations in demand for gas is shown in Figure 11.

Seasonal demand was discussed by virtually every witness from industry and government. Without seasonal demand, much of the rationale for storage other than for security disappears. Storage allows for increased purchases in summer, and less requirements in winter, thus smoothing out the peaks and valleys of the annual demand curve, creating a more efficient and economical system.

Description of Underground Natural Gas Storage

The principle of underground natural gas storage is straightforward. Through seismic exploration and drilling, a geological formation which can be expected to contain natural gas or oil is located. Such a formation is a layer of impervious rock with the shape of an inverted bowl or soup plate, below which is a layer of permeable rock capable of containing a fluid or gas, or both. If it contains fluid, the fluid will be oil or water, and if it contains gas, it will be natural gas. If the fluid is water, the formation is known as an aquifer. A simplified drawing of an underground storage facility is found in Plate 14.

The distance underground of underground natural gas storage facilities varies considerably. Some are 2,500 metres underground. By contrast Gaz Metropolitain of Quebec has storage in the former Laduboro field near Point Du Lac, some twelve kilometres west of Trois Rivieres, the top of which is only seventy-five metres beneath the surface. Seismic studies suggest that if suitable formations exist in the Fraser Valley, they would be approximately 1,000 metres underground.[8]

Distance underground is important for a number of reasons. First, as scuba divers learn in lesson one, pressure increases with depth. Gas can thus be stored underground at pressures which are substantially higher than surface pressure, but which are similar to the pressure of the surrounding water or rock. Thus, in relation to the ambient hydrostatic pressure, the gas pressure is in equilibrium. In principle this resembles the scuba diver at depth breathing compressed air at pressures that would be far in excess of what human lungs could withstand at the surface. As the breathing of this compressed air is at depth, and as the water pressure and the air pressure at that depth are in equilibrium, the scuba diver's lungs do not explode, and he or she suffers no ill effects.

Thanks to the caprock and the weight of the mass of rock, water, and soil overlying the caprock, it is also possible to pressure gas in storage underground to pressures above the ambient pressure of the depth; how far above ambient pressure is safe is a matter that can only be determined on

[7] The amount of B.C. gas that reaches California is not known with precision, as some of the gas sold to Washington and Oregon may be resold to California. The amount for which there is some information is small, approximately 4% of B.C.'s total export sales. This is expected to double or triple in the next decade, and may go much higher, depending on Alberta and U.S. deliveries to the same area, which in turn will depend on the permitting and construction of other pipelines, particularly the Pacific Gas Transmission pipeline, and on increasing restrictive air quality regulations that require the use of gas over other, more polluting, fuels. Particular note must be made of the November 1990, U.S. *Clean-Air Act*, the first important air quality legislation in 13 years.

[8] Fraser Valley Gas Project Summation, page 31, in the Commission Record.

the basis of a careful study of the geology of the area. The Herscher field in Illinois, which had problems associated with the escape of gas through the caprock, was a field where gas was stored at higher than ambient pressure. In a successful effort to deal with the problem, the pressure of the field was reduced.[9]

The surface facilities required for natural gas storage are not extensive. First is a compressor station, which typically takes up 2-4 hectares of land. It must be connected to each of the wellheads by pipe, and pipe must connect it to the major gas transmission pipelines. There is no requirement for the compressor station to be directly over any part of the field, or indeed, over the field at all. It can be located at any location within a half-dozen kilometres of the field, although a distant location will naturally increase the amount of pipe required. The compressor station will typically contain four to six compressors of approximately four thousand horsepower, cooling equipment, and water removal towers. The compressor stations for natural gas storage are similar to compressor stations on transmission pipelines to move the natural gas from production areas to markets. Many compressor stations, including at least one in the Fraser Valley, are currently in operation in British Columbia on the Westcoast system, and have been for the past thirty years, with very few complaints.

Storage in a Depleted Hydrocarbon Reservoir

It has been mentioned that the formation required for underground natural gas storage is the same as those formations in which hydrocarbons are found. Such formations are, generally speaking, the most desirable from the point of view of storage, as the existence of the oil or gas is evidence of good caprock above and good permeable rock below. They therefore require less testing and involve less risk, as production from the field will usually have provided much information of use to the gas storage operator.[10] Most North American (approximately 85%) underground natural gas storage facilities are located in depleted or partially depleted hydrocarbon reservoirs, which are not described as aquifer storage.

There is another economic advantage resulting from the existence of the natural gas in the field. The usable or working gas in a reservoir is generally about a quarter to a half of the total that is needed to create the system. The other half to three quarters is known as cushion gas, and cannot be used; its purpose is to maintain pressure. Much of the capital costs of underground gas storage reservoirs is for this unusable gas. Gas storage facilities in depleted fields may require less cushion gas to be injected, as some of the natural gas in the field that is not recoverable through exploitation can nevertheless serve as cushion gas. Nitrogen can also be used as cushion gas in certain limited applications. As in many other areas of underground natural gas storage, Gaz de France is the leader in this technology.

All witnesses agreed that aquifer storage, by reason of the untested caprock, is less attractive than storage in a depleted hydrocarbon reservoir. B.C. Gas has made it clear that they share that view. A future application for an aquifer storage facility from B.C. Gas to the B.C. Utilities Commission is unlikely if a natural gas field with commercial qualities is discovered. It is also unlikely for another, quite different, technical, reason — the chance of finding a suitable aquifer formation may not be high. The commission has had some difficulty understanding why opponents of exploratory drilling have assumed that an application for an aquifer storage facility is likely. It is not.

[9] Testimony of Dr. Rasin Tek, Transcript page 1224 ff., page 1242; Mr. Howard Griffith, page 1228; Messrs. Robert Means and Douglas Ball, page 1512.

[10] Testimony of Mr. H. Griffith and Dr. R. Tek, Transcript, pages 1160 ff.

Aquifer Storage

In the case of an aquifer, a number of injection/withdrawal wells are drilled through the caprock, in order to fill the structure with gas in summer and allow for withdrawal in winter. The amount of gas that can be stored will depend on the size and shape of the impervious rock that forms the cap of the formation. If too much gas is injected, it will fill the formation below the caprock, push the water beyond the structure's spill point, and escape from below the edge of the caprock at the spill point. Similarly, if the caprock has faults, gas can escape upwards. How the facility operates is shown in Figure 12.

The size of a storage facility is important, but two quick caveats should be noted. First, not all the gas in a facility can be withdrawn to satisfy winter demand. Only a portion, rarely one half, of the gas in the facility is working gas that can be used. The remainder, called cushion gas, remains in the facility at all times, and is needed to maintain reservoir pressure. This has important cost and delivery considerations. As noted, it is also possible to use a less costly inert gas (nitrogen) for up to 20% of the gas cushion. Second, the permeability and porosity of different aquifer formations will vary, leading to differing possible rates of injection or withdrawal of gas. Injection and withdrawal rates can be increased by increasing the number of injection/withdrawal wells, but inevitably there is a practical limit to expanding the facility's rate of deliverability. This deliverability limitation is generally a more important factor for the utility than the overall volume of the working gas that the facility contains.

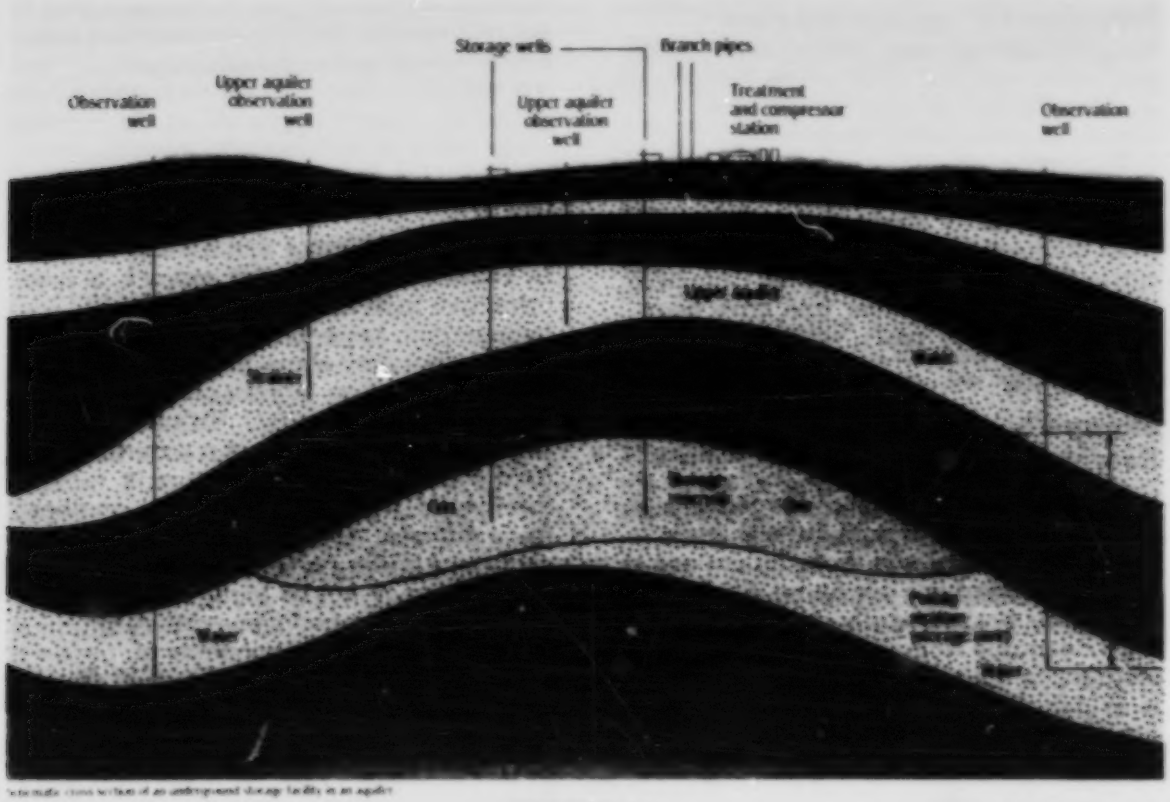


FIGURE 12

SOURCE: Gaz de France.

The Russell Aquifer Storage Proposal

A great deal was heard in the media during the commission's hearings about previous Canadian experiences with aquifer storage to the effect that it involved high risks. While these stories are worthy of note as examples of how creative journalists can be when other news is short, they are misleading. Ivan Cuthill of Consumers Gas, the company that examined aquifer gas storage possibilities of the Russell area near Ottawa, described the history of this at pages 1307 and 1308 of the transcript:

> *Mr. MacAdams: Now, I understand as well that your company has tried an aquifer storage possibility, but has not proceeded with that possibility. Perhaps you can give us the chronology there.*
>
> *Mr. Cuthill: Yes, that was years ago, actually before Tecumseh Gas Storage was formed between Consumers Gas and Imperial, and that was in an area known as Russell down close to Ottawa. And we instituted a pilot project to test the feasibility of storing gas in an aquifer that we had determined in drilling, and it was unsuccessful in the pilot stage, so we abandoned the idea.*
>
> *Mr. MacAdams: How far along the pilot stage did your company go before deciding to abandon?*
>
> *Mr. Cuthill: We drilled I believe it was five wells and put in a small portable compressor and started injecting into the aquifer, and quickly determined that it was — the integrity of the aquifer could not be maintained, and we subsequently abandoned it at that point. I can't tell you specifically how much gas we injected in, but it didn't take us long to determine that it was not going to work.*
>
> *Mr. MacAdams: Were any local residents put to any inconvenience or risk by this activity?*
>
> *Mr. Cuthill: No, sir.*

Other geological formations have been tested and not proceeded with for a variety of reasons, in locations as far apart as northern Spain, the Tokyo plain, and Hampshire, England. All that such experience proves is that the B.C. Utilities Commission hearings on storage (assuming there is an application and such a hearing takes place) should be thorough, and further, even if a project gets approval to proceed, it can be terminated later without harm if the early development shows any problems. The Russell experience suggests safety, not risk.

The Economics of Storage

A discussion of the economics of any natural gas storage facility in the Fraser Valley at this time is inevitably hypothetical. At this stage, without the geological data that exploratory drilling might provide, it is not possible to know or quantify with precision many of the economic variables inherent in such a project.

B.C. Gas has calculated that if drilling determines that the geology is favourable and an aquifer storage facility can be created, the costs of development may be approximately 104 million dollars and the savings to customers per year will be in the neighborhood of 30 million dollars, with a further saving to others of another 35 million dollars.[11] B.C. Gas has stated that these figures are conservative estimates. After examining the economic data presented, particularly on the costs of alternatives, and after discussions over the summer on the value of gas storage facilities with operators in Ontario, Washington, California, Oregon, Michigan, Illinois, Missouri, France and Italy, the commission agrees. Further, the testimony of Mr. Art Willms as to the costs of expanding the Westcoast transmission system suggests that benefits may be

[11] Testimony of Patrick D. Lloyd, Transcript, pages 1017 ff. and Commission Exhibit T-42 (A), page 7.

higher than B.C. Gas calculated in its presentation.[12]

It has been explained above that the discovery of a natural gas production field in the Fraser Valley might lead to a future natural gas storage facility in the partly depleted field. This could result in greatly reduced costs as compared to those associated with the development of an aquifer natural gas storage facility. This was not dealt with in depth by the B.C. Gas presentation. In keeping with their conservative approach to the economics of underground natural gas storage, the company has dealt cautiously with variables such as the find of a producing field that might reduce the costs of establishing a gas storage facility in the future. The possibility nevertheless exists, and if such a field were found, the savings from gas storage might be well in excess of the projected $65 million figure. The find of a gas storage formation larger than the one on which the projections are based would also improve the financial benefits.

Needle Peaks

The pages above discuss general temperature induced gas purchase trends. Not mentioned are the peak delivery problems, at certain times of the day on the very coldest days of winter, well described by the industry term "needle peaks".[13] Because of cold weather in winter, the system as a whole is using more energy. However when customers return to their homes in the late afternoon, turn up the thermostat, draw hot water for showers and turn on their stoves, the demand jumps sharply, and cannot be met by the usual deliveries. At such times the utility company must reduce demand by cutting off deliveries to some customers (interruptable service), or increase deliveries by such means as drawing down the stock in storage facilities.

Underground natural gas storage is not the only means of supplying such peak power requirements. Liquified natural gas in storage, or gas under pressure in pipelines, may provide some of the required peak shaving. Similarly it is possible to use propane from storage in some limited applications.

Alternatives to Fraser Valley Production or Storage

LNG

Unfortunately there are clear limitations to methods of supplying peak demand. Costs for LNG, for example, average many times the cost of underground natural gas storage. Mr. Lloyd of B.C. Gas testified[14] that B.C. Gas had calculated that an LNG facility capable of providing ten billion cubic feet of storage would cost approximately ten times as much as would underground storage. Mr. Ely of Washington Water Power Company was of the view that this figure was high, but that it would cost at least four times as much.[15] From its inquiries of gas companies elsewhere the commission does not doubt that these figures are reasonable ball park approximations. The differences between the estimates are accounted for by differing cost factors for different facilities.

In addition to cost there are also safety concerns about LNG. Public fears over extensive above ground LNG storage in populated areas would be high, as

[12] A point noted by Mr. Lloyd of B.C. Gas at page 1037 of Transcript, where he indicated that the Westcoast cost expansion figures presented to the commission by Mr. Willms indicated that the $30 million per year figure may be ten or twenty million dollars too low.

[13] Mr. Willms of Westcoast Energy described this situation in his testimony at page 962 of Transcript, as did Mr. Ely of Washington Water Power on page 819.

[14] Transcript, page 1077.

[15] Transcript, page 855.

accidents elsewhere[16] suggest the risks are substantially greater than for underground natural gas storage.[17] The question and answer of Commission Counsel Douglas MacAdams and Mr. John Thrasher of B.C. Gas is interesting in this regard:[18]

> *Mr. MacAdams: And there is, as well, the absence of clamour from communities wanting to have LNG plants in their areas?*
>
> *Mr. Thrasher: Yes, I would say there is definitely an absence of clamour.*

At the present time the LNG storage facility on Tilbury Island can provide 150 million cubic feet of gas daily for a maximum of four days. For comparison, the largest LNG plant in Canada is that of Gaz Metropolitain, which has two double walled steel tanks 45 metres high and 46 metres in diameter near Montreal. The two tanks hold 56 million cubic metres (2 Bcf) of natural gas. In volume terms, this is equivalent to two or three days of winter consumption for the city of Montreal. The daily winter flow rate from these tanks is 6.8 million cubic metres, or 240 million cubic feet. This is approximately a quarter of Gaz Metropolitain's highest winter demand day of 4 December 1989. B.C. Gas' LNG facility could handle roughly the same proportion of the Lower Mainland's peak load.[19]

Propane

The use of propane to handle needle peaks has limited application. Propane can be substituted for natural gas, but for various technical reasons the percentage of propane has to be kept low, in the neighborhood of 12-15%.[20] Further, storing propane is not without extensive costs of its own. Above ground storage in steel steel containers is similar to LNG storage, with similar costs. For storage in large quantities, underground storage is the most desirable option, but this is probably less safe than storage underground of natural gas. There is a possibility that propane might be stored underground in abandoned B.C. mine shafts, but this was not discussed at any length before the commission. The Commissioner visited the site of an underground propane storage facility in Missouri. The caverns used were mined specifically for the propane storage. It contains some 33 million gallons of propane, the energy equivalent of 2.9 billion cubic feet of natural gas. It appeared to have greater environmental risks, as propane has different and less attractive properties than natural gas both as a fuel and for underground storage. For technical reasons there appear to be few advantages in substituting underground storage of propane for underground storage of natural gas, particularly when such substitution can only handle a small percentage of peak requirements.

Salt Caverns

Natural gas can also be stored in salt caverns underground, which are either of natural formation, or, more likely, the result of injecting water which dissolves the salt and thus creates a cavern. There are a number of such structures in Western Canada, but none in British Columbia.

Abandoned Underground Mines

Natural gas can be stored in caverns underground, such as abandoned coal mines. While there are many abandoned underground mines in British Columbia, no serious proposal to use such facilities

[16] For example, the 1983 above ground gas storage fire in New Orleans, Louisiana.

[17] Interesting information about LNG risks, including some calculations of risk figures, are found in R. Keeney, R.B. Kulkarni and K. Nair, "A Risk Analysis of an LNG Terminal", *Omega*, Vol 7, 1979, pages 191 to 205.

[18] Transcript, page 1077.

[19] Transcript, page 1050.

[20] Personal communication between Commissioner and Laclede Gas Company, St Louis, Missouri, 10 October 1990.

for that purpose was made or heard during the existence of the commission. It was accordingly not considered, but the commission notes that old mines or newly constructed caverns in rock are in use for storage in other jurisdictions.

Pipeline Storage of Gas

Another possibility is the prospect of obtaining stored gas from existing pipelines. This requires pipelines not in use for other purposes, and is a valid, if very limited, option when such unused facilities exist. British Columbia lacks any appreciable amounts of such unused pipeline facilities. To construct such pipelines specifically for storage would be a higher cost solution than above ground LNG in steel tanks.

Short Term Service Contracts

Through short term service contracts with producers in the northeast of the province, B.C. Gas is able to obtain limited pipeline capacity in the Westcoast transmission system to assist with the high loads of winter.[21] Short term service contracts are agreements with producers who have contracts with Westcoast Energy on an annual basis for the transportation of a set amount of gas every month. B.C. Gas purchases this gas for the four or five months of the winter period, and the producer sells its gas during the other seven months of the year to other purchasers. It will readily be seen that this system is also highly dependent on storage elsewhere. The market in the remaining seven months of the year may very well be a U.S. utility company desiring to fill a storage facility in the summer months when gas is cheaper. Thus, indirectly, B.C. Gas may rely more on storage at the present time than the figures for Jackson Prairie suggest. Jackson Prairie currently supplies 61 million cubic feet of gas a day during the winter, while short term service contracts provide 59 million cubic feet. By contrast, the daily winter delivery from Westcoast is approximately 360 million cubic feet.[22]

The East Kootenay Link

The East Kootenay Link is a pipeline connection between the pipeline of Alberta Natural Gas, which runs from Pincher Creek to Kingsgate in the East Kootenays, and the B.C. Gas Inland Division pipeline near Trail. This pipeline in turn continues to the Merritt/Kamloops area. At first glance of the map, this southern link from Alberta to the Westcoast Energy system appears to be a possible alternative to the Westcoast northeast to southwest pipeline.

This initial attractiveness evaporates under closer scrutiny. First, the line is a 12 inch line, which simply does not have the capacity to make an appreciable difference to the Lower Mainland market in winter. Second, much of the capacity of the line is taken up in supplying existing B.C. interior customers, who in the event of a break in the Westcoast line or some other interruption to the consumers of the Lower Mainland, would be unlikely to be willing to forgo their energy source. This position is readily understandable. Third, the line carries only Alberta gas, and this is likely to continue unless southeastern B.C. petroleum exploration results in a find of commercial quantities. Thus purchasing such Alberta gas at short notice to substitute for the interrupted supplies from the Peace River presents acquisition problems. In the case of longer term contracts, there might be a need for extending the gathering system in Alberta to meet this new demand — which, as it would be a winter only demand, would have the same problems as are outlined below with respect to expanding the gathering system of the Peace River. Finally the line connects to the Westcoast system above the Coquihalla. Thus the

[21] Testimony of Mr. John Thrasher, Transcript, page 1042.

[22] Transcript, page 1042.

extra security provided by the line is questionable.

The possibility of expansion of this line was mentioned by Mr. Lloyd of B.C. Gas. He stated that the company had done rough cost estimates, which indicated that it would cost roughly twice what an aquifer storage facility in the Fraser Valley might cost. The commission has concluded that while this line might provide in the future to be of some marginal value in supplying the Lower Mainland, it does not provide an effective or reasonably priced alternative, either from the economic or environmental point of view, to natural gas production or storage in the Fraser Valley.

Expansion of the Westcoast System

During public hearings in the Fraser Valley, a frequently asked question was why storage was preferable to expanding the pipeline facilities to allow for the general increase in winter demand, and for the needle peak demands of the hours of greatest consumption on the coldest winter days. The answer to this question is twofold — cost and efficiency.

Economic Factors

The cost argument is straightforward. Increasing the size of the delivery system, through increasing the size of the gathering system in the northeast, looping of the existing pipeline, and expanding the compressor facilities along the pipeline, is technically possible. Mr. Art Willms, of Westcoast Energy, testified that by completing some sixty miles of looping at approximately 20 locations on the Westcoast system, which would cost approximately $100 million, another 200 million cubic feet per day (or some 14%) capacity can be obtained.[23] However, to increase the capacity by another 250 million cubic feet per day would require some $330 million of expenditure. To add 550 million cubic feet of daily capacity would cost an additional $765 million, or an increase of $435 million for the marginal 300 cubic feet of gas per day.

The economic problem presented by such expansion is that the facilities would be in full use for only two or three winter months. Indeed, were the expansion to take account of peaks, some of the expansion would only be of use for some weeks, or even some days, of the year. The result is a high cost structure, which inevitably will be reflected in consumer prices and in reduced demand for natural gas. It also inevitably results in other goods and services that our society may wish — better hospitals, schools, colleges and universities, roads, airports, rapid transit systems — being delayed, reduced in scale, or even denied.

This leads to the second problem of expanding the gathering and transmission systems, namely the environmental impact.

Environmental Impact of Expansion

Expanding a gas transmission system for use only during the two or three months of the coldest part of the year is highly wasteful in the environmental sense. Pipeline and compressor manufacturing requires steel, energy, plastics, machinery, and a host of other products, the creation of which has extensive environmental effects and costs. Putting such products into or on the ground requires extensive use of machinery, and directly impacts the land used, land which frequently is also being impacted adversely by many other human activities. Further, the expansion of the gathering system in the northeast will have adverse gas conservation impacts. Gas recovery from a field is not maximized by having heavy demand for short periods, followed by reduced or non existent demand for the rest of the year. Conservation of this energy source is achieved through steady demand at a rate which maximizes the recovery from the field.

[23] Transcript, page 965.

It should be noted that an underground natural gas storage facility in the northeast can help manage this problem. Indeed, British Columbia's only underground natural gas storage facility, at Aitkin Creek, is valuable from this point of view. While not near the point of consumption of the gas, it nevertheless helps dampen the fluctuations in demand for the gas in the northeast, and thus allows the gathering systems to operate more efficiently than would otherwise be the case.

Finally, substitution of gas for other fuels is a very important element of any strategy to reduce the environmental effects of fossil fuel combustion. The first recommendation of the fourth report of the House of Commons Standing Committee on the Environment, stresses:[24]

> *. . . the need for fuel substitution away from high-carbon fuels and for the commercial availability of technologies for exploiting carbon-based fuels with less environmental impact.*

This report and others like it reflect the conclusions of the first World Climate Conference held in Toronto in 1988, and its successor, the Second World Climate Conference, which concluded its sessions in Geneva in early November of 1990. Whether these scientists are correct in their gloomy predictions regarding global warming is not an issue for this commission.[25] Suffice to say that prudence suggests a conservative approach. The risks of global warming require active steps to reduce carbon dioxide and other greenhouse gas emissions.

In its justification for the financial incentives provided to build the natural gas pipeline to Vancouver Island, the Government of British Columbia, well before the release of the House of Commons report or the Toronto Conference, expressed similar views on the importance of encouraging the use of natural gas to reduce low level photochemical pollution, to improve regional air quality, and to reduce the effects of fossil fuel combustion on global warming. Increasing the cost of the fuel by way of developing a collection and transmission system that operates for only a fraction of the year inevitably will keep some potential users away from gas as a fuel, and inevitably will cause some existing users of the fuel to turn to oil, coal, electricity, or some other less environmentally attractive source of energy. In short, from an environmental point of view, expanding the pipeline system to accommodate winter demand has many undesirable effects. By contrast, improving pipeline efficiency by permitting better year round utilization has substantial environmental benefits.

Export Curtailment

The issue of exports came up frequently during the public hearings. The theme of the comments was generally to the effect that without exports, drilling in the Fraser Valley would be unnecessary, as excess capacity would be available on the Westcoast transmission system to bring natural gas from the Peace River to the Lower Mainland in winter.

The issue of gas exports from B.C. have been discussed many times before, and no doubt will continue to be discussed in the future. It was the subject of its own Commission of Inquiry in the early eighties.[26] This commission intends to restrict itself as far as possible to the aspects of exports that affect the need for exploratory drilling in the Fraser Valley.

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[24] House of Commons Standing Committee on the Environment, "No Time To Lose: The Challenge of Global Warming", October 1990, p. 5.

[25] For the record, MIT, the University of Alabama and NASA believe the danger is overstated; the U.S. Goddard Space Center, the UK Meteorological Office, and the University of East Anglia hold that global warming is a serious threat.

[26] Province of British Columbia, *Commissioner Inquiry on British Columbia's Requirements, Supply and Surplus of Natural Gas and Natural Gas Liquids*, G.W. Govier, Inquiry Commissioner, 1982.

Given the existence of the Free Trade Agreement, proposals to limit exports of natural gas now have an unreal quality. Energy resources are not exempted from the Free Trade Agreement, and indeed, were an important part of the United States interest in the deal.

The reason for this American interest is not difficult to understand. Secure, close-to-home energy supplies will become increasingly important to the United States, which currently obtains less than half of its crude oil from domestic sources, and expects to obtain only half of that from domestic sources at the end of the decade as Alaskan supplies diminish. Further, given strong environmental concerns of Americans, particularly Californians, natural gas is the fuel of choice where choice exists.

There is also an ethical argument that must be addressed, namely the propriety of restricting our neighbors from sources of fuel which we have led them to believe will continue to be provided, and which they believe to be important to their future. Given that for more than half of its existence this province purchased all its petroleum products at market prices from the U.S. without let or hindrance, the question is a real one. Further, Canadians have not hesitated over the past 15 years to tell our American cousins what to do about acid rain, and what fuels to use. Two months after the passage of the U.S. *Clean-Air Act* would be an extraordinary time to consider curtailing gas exports.

A full consideration of the issue would require an analysis of what are our rights and duties to the international community, what obligations to provide resources to those who believe they require them, and what is the impact of international agreements on such matters. However, it does not need to be discussed either in the fairness section or in this section of the report. Cutting off or reducing exports should be rejected strictly on the grounds of self interest.

Assuming that British Columbia is in a legal position to reduce exports to the United States for other than emergency reasons, and has decided it is ethically correct to so do, would such a cut in exports deal with the need for drilling in the Fraser Valley?

At first glance, the answer is yes. The winter requirements of the Lower Mainland, and, in due course, Vancouver Island, could be met by the existing gathering in the northeast and transmission facilities from northeast to southwest. Exports currently take about 40% of the throughput of the pipeline (Figure 13), and this capacity could be devoted to domestic use.

With closer scrutiny, the answer is less clear. The exports that currently take place, combined with the B.C. Gas storage at the Jackson Prairie storage facility, allow B.C. Gas to divert to B.C. some of the throughput that would otherwise go to Washington, Oregon and California on peak load days. Thus there is not 40% of the total capacity on those days to be diverted to British Columbia deliveries. A part of that 40% of Westcoast's total export throughput is already diverted to the Lower Mainland.

From the quick description above it appears that cutting off exports (except in the low volume summer months) might provide some of the extra capacity needed. But such an approach is not without costs of its own.

The first cost is higher dollar cost to the British Columbia consumer. The scenario above would still allow for some deliveries to the United States, but they would be at different times of the year, and in different amounts, than at present. In addition, the supply would be reduced at the very time the Americans needed it most, namely in cold winter periods, such as December of 1990. Thus it can be expected that current U.S. customers, particularly those in the Seattle area, would turn to other, more reliable sources. This would involve pipeline delivery

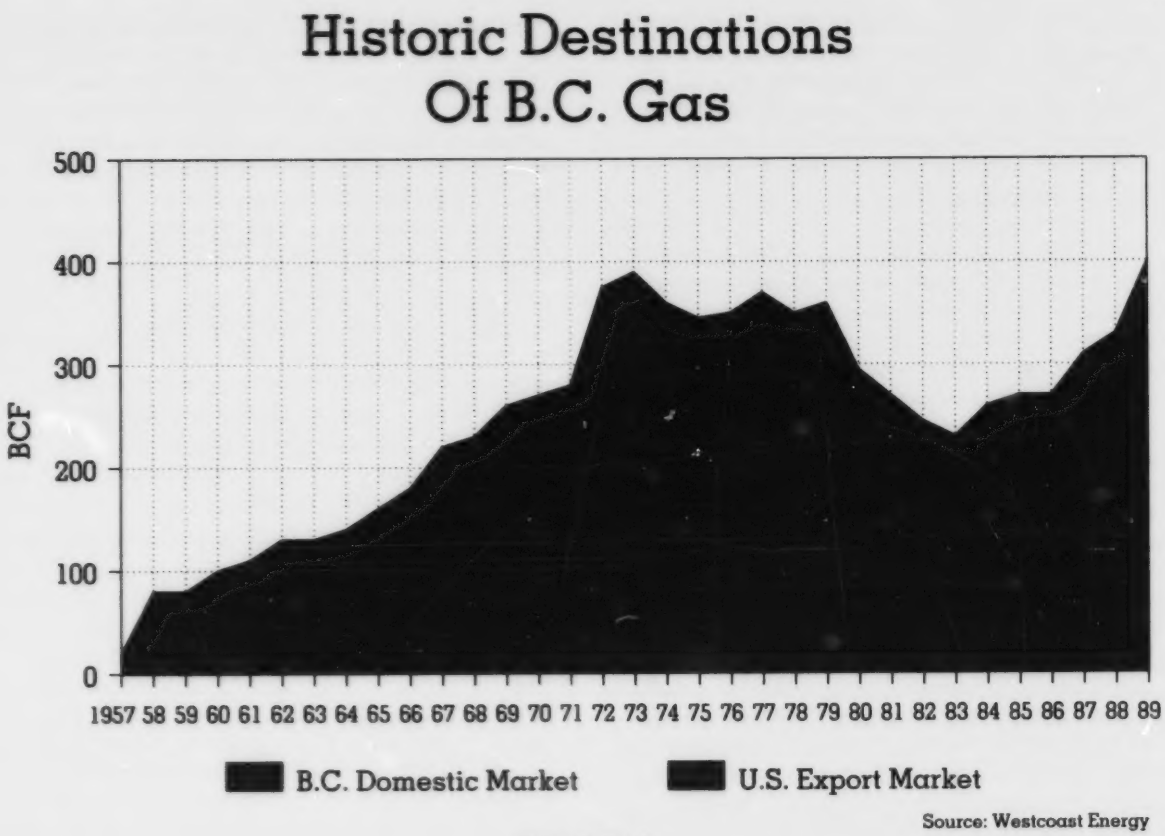

FIGURE 13

changes to provide Seattle with Albertan gas, and to provide the city with access to the Jackson Prairie facility. The net result to British Columbia is that our own Westcoast transmission pipeline would not be carrying export gas in as large quantities as it is at the moment, and would not be working at the effective levels of today. Thus costs to British Columbia consumers would increase. This will have an across the board impact on industries that use energy in substantial amounts, will reduce revenues from the industry to the provincial treasury, and will impact consumers directly.

This is not just a question of all of us having a few dollars less in our pockets. Creating a poorer society is likely to result in marginal decreases in such services as hospitals, ambulances, school earthquake retrofitting, less paint and painters for school crosswalks, less money for pulp mill clean up, and so on throughout the whole range of society's activities. It thus results directly in less safety, and higher mortality and morbidity than would otherwise be the case. The term coined by Professor Aaron Wildavsky of the University of California — "Richer is Safer" — neatly describes this effect.

On the environmental side the results can be expected to be much more negative than on the economic. Other more polluting fuels will become cheaper relative to gas, and their use will either expand, or not drop as quickly as would otherwise be the case. New uses, such as for natural gas vehicles, will not develop — indeed, the population of natural gas

vehicles, conversion to which now has an economic threshold of about 130 dollars a month in gasoline costs, will probably grow even slower than at present, or possibly decline, as the threshold may move up towards 200 dollars a month in gasoline costs.

Thus the restriction on exports, even if possible, is definitely not recommended as a way of dealing with the issues contained in the terms of reference of this report. Restricting exports will raise costs to individuals and industry in British Columbia, it will increase mortality and morbidity, and it will maintain or increase the existing level of environmental degradation. The potential benefits appear small in comparison.

B.C. Customer Service Curtailment

Another method of dealing with the problem of restricted winter transmission facilities is to reduce the customer load, or more correctly in the case of B.C. Gas, to restrict its growth. This can be done in three ways: first, through interruptable power contracts to certain customers; second, by exhorting the public to turn down the thermostat, close off rooms that are not needed and otherwise reduce their gas consumption; and third, by outright refusal to connect up would-be new customers to the system.

At the technical hearings, Mr. Lloyd of B.C. Gas discussed the first possibility at some length, but without much confidence that any breakthroughs were likely. He described the company's efforts to create differential prices to encourage the interruptable customer base, and the generally lukewarm response of potential interruptable customers to such pricing schemes. He also indicated that the company is having a difficult time keeping interruptable service customers in that category, as according to Mr. Lloyd, despite attractive pricing schemes, some of the interruptable service customers wish to become firm customers, i.e., customers who cannot be interrupted. Mr. Lloyd stated:[27]

> *As a matter of fact, the customers tend to be going the other way. That even though the interruptible rates are cheaper, they are tending to look for firm supply. Some of our interruptible customers are asking us to convert to firm.*

The commission is of the view that B.C. Gas could probably do more in this area, but the results can only be expected to be marginal. The company will also require some government support, as it clearly regards its legislative mandate under the *B.C. Utilities Act* as providing gas to any person or organization within its service area that wants it and is willing to pay for it. Interruptable power is not entirely on all fours with this legislative mandate, and the government, if it wishes to see this method used to reduce winter peak loading, might well clarify the company's legislative mandate to spell this out. Were the government to reject exploratory drilling for gas in the Fraser Valley, this should be considered.

The second option, exhorting customers to help reduce load, has been resorted to by B.C. Gas. Indeed, only in the past month television and radio messages have urged its customers to demonstrate good citizenship and reduce their demands on the system. There have been some interesting experiences elsewhere of such appeals; they do not always work, and they in fact may sometimes be counterproductive, as people anticipate cuts in service by turning the thermostat up, not down. All in all, the commission is of the view that this will not be a major factor in demand reduction at peak times, particularly if the appeals to the public are frequent and become routine.

Given B.C. Gas' legislative mandate under the *BC Utilities Act*, the prospect of not accepting new customers is not currently a realistic option for the company. Were the government to regard this as a necessary

[27] Transcript, page 1080.

course of action, change of the legislation would be needed.

Although B.C. Gas naturally has shown no enthusiasm for such a policy, it is a possible option in the short run, which might be necessary if the lengthy time frames for development of production, transmission, and storage result in a period of natural gas shortfall. This is not as radical as it sounds; it has happened before in many other jurisdictions. Indeed, during the sixties and seventies, the City of Victoria had a gas distribution system which resolutely refused to accept new customers, as newly arriving chefs of the city's restaurants discovered to their dismay.

While it is a possible option, it is not one that the commission recommends. There has been a consistent provincial government policy over the past few years of expanding the use of gas. Crown agencies, such as B.C. Hydro, have had similar policies. Regulated private utilities such as B.C. Gas have followed suit. The rationale of the policy is the laudable goal of improving air quality.

The provincial government, for example, took the lead in establishing the Vancouver Island Gas Pipeline, despite considerable reluctance from the other two levels of government and of industry — the federal government on the issue of cost and subsidies, and the municipal governments of Vancouver on the issue of routing the line through the Greater Vancouver Watershed. Industry, specifically the forest industry, is very unhappy with what it considers to be heavy handed government direction as to what fuel it will be required to use in the six affected pulp mills.

B.C. Hydro, for its part, has had policies to encourage consumers to convert from electricity to gas for water heating, and to convert from wood fireplaces to gas fireplaces. B.C. Gas has followed the B.C. Hydro lead in encouraging the use of natural gas generally, but in particular as a vehicle fuel, with the result that British Columbia has become a world leader in this field, even to the point where the B.C. Research Corporation has a research and development contract with Caterpillar, Inc. and the Technology Advancement Office of the South Coast Air Quality Management District in southern California for the development of a mass flow sensor to precisely control the air/fuel ratio in natural gas truck engines. Also noteworthy is the development of a home refueling unit, the FuelMaker,[28] designed to allow refueling of natural gas vehicles at home overnight.

For the government to deliberately adopt even a temporary policy of customer curtailment obviously would create difficulties with respect to its commitment to the fuel and about the security of future supplies. Those who have previously supported the government moves to encourage gas over other fuels, for example environmentally concerned citizens, will be unhappy with what will be perceived as at best a delay in policy implementation, and at worst a reversal of the policy itself. It would also cause difficulties with those who have had reason to oppose or object to the application of the policy. The two hundred and fifty million dollars of expenditure to bring natural gas to Vancouver Island, for example, would be generally regarded as having little overall benefit if at the same time as the Island transmission and delivery system was being developed, the growth of the natural gas delivery system was being curtailed on the Lower Mainland by reason of a lack of supply.

Further, the reaction from persons or industries which regard themselves as being adversely affected by this policy in the past could be expected to be critical. Those who are at present opposing the routing of the Island pipeline through their properties would likely be hostile, as would the forest industry on the Island.

[28] FuelMaker was launched in August of 1989. FuelMaker Corporation is composed of three equal partners: B.C. Gas, Questar Corporation of Salt Lake City, Utah and Sulzer Brothers Limited of Switzerland.

Moreover the mayors of the Greater Vancouver area could be expected to be most unhappy over such a policy. First, their objections as to routing the pipeline through the watershed were overruled by the government,[29] and second, their constituents would not be able to hookup to natural gas by reason of lack of supply.

Jackson Prairie Storage

A potential alternative to a Fraser Valley storage facility is underground gas storage in Washington State. At present there is a storage facility at Jackson Prairie, near Chehalis, some 80 kilometres south of Olympia, Washington. One of the three companies which own and operate this facility has leased space in it to B.C. Gas. Thus at the present time B.C. Gas does have storage. It should be noted, however, that this B.C. Gas storage capability, and the B.C. Gas owned gas that is pumped into the facility in summer, does not result in this stored gas ever returning to B.C. for use by consumers in the province. Instead, when B.C. Gas requires extra supplies for the Lower Mainland market, it provides gas from its storage to U.S. gas utilities, principally Northwest Gas of Portland, and in turn gas coming through the Westcoast pipeline that was originally destined for Northwest Pipeline is diverted to the Lower Mainland market.

The system as it now exists has a number of uncertainties. First is the length of time B.C. Gas will continue to be able to lease the storage volume it now has. Its current lease was signed on 1 May 1989, and, at the option of either party giving a year's notice, expires on 30 April 1996 or on any subsequent 30 April. Testimony on this was not conclusive, but the concern of B.C. Gas that such storage might not be available after that date appears to the commission to be well founded. Mr. Gary Ely, the Vice President of Marketing, Sales and Gas Supply for the Washington Water Power Company, one of the three companies in the partnership owning and operating the Jackson Prairie facility, spoke on this at the technical hearings.[30] He stated that one reason for the termination date of 30 April 1996 for the existing B.C. Gas lease was to take into account possible expansion of the requirements of the three partner companies.[31] Further, uncertainty over completion of other pipeline construction (the Pacific Gas Transmission pipeline, to deliver Alberta gas, scheduled to be completed in 1994) combined with market growth (the number of customers of this utility is expected to grow 40% in the next five years; the other two Washington State utilities who jointly own Jackson Prairie with Washington Water Power, namely Northwest Pipeline Corporation and Washington Natural Gas, are experiencing similarly high growth rates) and uncertainty by reason of regulation of the Federal Energy Regulatory Commission and the regulators in the states of Washington and Idaho, suggested that further storage capacity might be needed by the owner companies in the mid 90s.

Conclusion

In short, the methods of reducing winter demand for natural gas outlined above do not appear likely to be solutions for the problem. All but expansion of the Jackson Prairie facility appear to be higher cost solutions, and that option has the disadvantage of considerable uncertainty, uncertainty over which the British Columbia government and B.C. Gas have very little control. From the environmental and economic point of view, increasing supply during the winter period through a production field in the Lower Mainland, or establishing storage facilities, appear to be more attractive options to pursue.

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[29] Province of British Columbia, *Report of the Coquitlam Watershed Pipeline Inquiry*, Douglas L. MacKay, Inquiry Commissioner, July 1989.

[30] Transcript, page 832 ff.

[31] Transcript, page 834.

Regulatory Reform Applicable to Underground Natural Gas Storage

The commission notes that underground natural gas storage is currently practiced in British Columbia, and notes further that the absence of legislation in this area has led to public concerns. Whether or not another underground natural gas storage facility is established in the province, it would appear appropriate at this time to bring our legislation up to date to take into account current practices. In spite of recent amendments, the *Petroleum and Natural Gas Act* and the *Drilling and Production Regulation* are deficient in several respects.

Neither the Act nor the Regulation prescribe technical standards for storage reservoirs. While several approaches are possible, the commission concludes that the following approach is most suited to this province's needs.

RECOMMENDATION 1

Minimum Technical Standard for Underground Storage Areas

That a minimum technical standard be added to Part 13.1 of the **Petroleum and Natural Gas Act** ***to require that underground storage facilities be permitted only in impervious strata which will effectively confine the stored gas, or other hydrocarbon.***

In 1989, the Canadian Standards Association Task Force on Underground Storage of Hydrocarbons produced a report recommending the development of a national technical standard for underground storage areas, to be developed by representatives of both industry and regulatory agencies. It was proposed that the standard might include the following topics: location of reservoir; well drilling and construction; design, development and selection; surface facilities; operations and maintenance; monitoring and measurement; safety; plugging and abandonment; and records. Of course, many of these issues are already addressed by the B.C. Act and Regulation. This standard would be most useful in setting guidelines for reservoirs located in this province.

RECOMMENDATION 2

Adoption of CSA Task Force Technical Standards

That should the 1989 recommendations of the CSA Task Force on Underground Storage of Hydrocarbons result in the production of a national technical standard for underground storage areas, such a standard, or selected parts of it, be incorporated in the **Drilling and Production Regulation** ***or the Ministry's Procedural Handbook.***

To assist the Ministry in monitoring the ongoing operations of underground storage reservoirs, the enactment of detailed reporting requirements is indicated. At present, Divisions (38) to (42) of the *Drilling and Production Regulation* are essentially aimed at the reporting of drilling, not storage, operations. These reports might include a wide variety of data and could be required on a semi-annual basis. Required information might include maps, information on wells previously drilled in the strata concerned, efforts made to ensure those wells have been properly plugged, storage pressures, and caprock integrity. It would be advisable to amend either s. 140.7 or s. 141 of the *Petroleum and Natural Gas Act* to

ensure that the Minister may make such regulations.

RECOMMENDATION 3

Reporting Requirements — Underground Storage Areas

That a new Division (42A) of the Drilling and Production Regulation *be enacted, setting out the reporting requirements for operators of underground storage areas.*

A common method of identifying the stored gas in a given reservoir is the use of tracers. Some tracers can be a slight source of potential contamination. Very small quantities are used, but some are radioactive. The half life of the radioactivity may be only a matter of hours. Reservoir operators commonly use tracers to detect migration from one reservoir to an adjacent reservoir or to distinguish stored gas appearing at the surface from natural sources. Tracers might also be of use, therefore, where an operator denies that gas arriving at the surface causing damage to third parties originated from the storage reservoir.

The authority to make such regulations derives from the *Petroleum and Natural Gas Act*, s. 140.7(b). The commission recommends that the use of tracers be regulated as follows.

RECOMMENDATION 4

Tracers Used Only With Approval

That the Drilling and Production Regulation, *in a new Division (36A), require tracers be used only with written approval of the division head or an officer of the division.*

RECOMMENDATION 5

Use of Tracers May Be Ordered

That the Drilling and Production Regulation *provide that the division head may order the use of tracers in an underground storage area to assist in establishing or eliminating an underground storage area as a source of gas.*

Finally, the B.C. legislation does not currently provide a mechanism by which the developer of an underground storage area can acquire the interest in non-recoverable native hydrocarbons held in private ownership, i.e., by those landowners retaining subsurface rights. Title to this gas must be extinguished before gas can be injected into the formation. This is so because parties holding interests in original gas may claim ownership of a portion of any injected gas subsequently removed from the reservoir and demand an accounting. This gap in the B.C. legislation could give rise to legal impediments which would delay development of the underground storage area, cause additional expense, or even prevent the development of an otherwise acceptable storage scheme.

Part 3 of the *Petroleum and Natural Gas Act* might be expanded to provide for a mediation and arbitration process to resolve these issues. Such a process might include a provision that the developer pay a deposit into a trust account, to be distributed to mineral rights owners in accordance with a decision of the Mediation and Arbitration Board. Once the deposit is paid, the developer would be authorized to proceed with the storage area scheme.

RECOMMENDATION 6

Acquisition of Other Interests in Non-Recoverable Hydrocarbon Deposits

That a legislative structure be established to provide for the fair and timely condemnation of third party interests in commercially non-recoverable original gas and for compensation for that condemnation.

The most widespread concern over exploratory drilling expressed at the public meetings held by the commission in the Fraser Valley was with respect to possible groundwater contamination. For much of the Fraser Valley, particularly the eastern Fraser Valley, water from wells is the primary or even the only source for domestic, agricultural, and industrial use. Approximately fifteen to twenty thousand water wells have been drilled or dug in the area, of which approximately half are in current use, and half abandoned. The depth of these wells ranges from a few feet to over nine hundred feet, with the majority being in the neighbourhood of one to two hundred feet. Some of the deeper wells draw from aquifers above which there are overlying aquifers of saline water.[1]

Although the growth of urban communities may lead to the establishment of municipal water systems, this reliance on groundwater is unlikely to change greatly in the near future. New municipal systems, like some of the existing systems, may continue to rely on groundwater for supply. The cost of establishing a water catchment and delivery system similar to that of the Greater Vancouver Water District and the western Valley for this area probably would be in the one billion dollar range.

The agenda of the commission reflected this public concern. To study and address the issues raised by the groundwater issues, the consulting engineering firm of Piteau Associates was retained to carry out a detailed analysis of all aspects of groundwater. In addition, an afternoon and part of an evening of the technical sessions were devoted to the issue. Three hydrologists, Mr. Allan Dakin, Vice President of the Groundwater Section of Piteau Associates, Mr. Hugh Liebscher, the regional hydrologist of Environment Canada, and Mr. Al Kohut, head of the Groundwater Section of the Water Management Branch of the Ministry of Environment testified. Valuable additional comments were also received from Mr. Dick McNichol, of C.P.I. Equipment Ltd. of Langley, the President of the British Columbia Water Well Drilling Association.

The groundwater concerns took a number of forms, involving many phases of exploratory drilling and of underground gas storage.

Contamination from Drilling Mud

The first concern that will be considered is possible contamination from drilling mud. The term drilling mud is self explanatory. In its simplest form it is a mixture of clay (bentonite) and water used in drilling to achieve three objectives: first to stabilize the walls of the hole and keep the hole open for the drill bit; second, to prevent gas or water under pressure at the drill bit from venting upwards; and third, to move the cuttings of rock up and away from the drillbit.[2]

Possible sources of contamination come from the mud penetrating porous sections of the walls of the wells, from contaminants brought up from lower levels spilling on the ground, or from improper disposal of the mud residues.

While there have been examples of contamination elsewhere in the world in jurisdictions without the technological expertise and level of supervision from government authorities that exist here, it is worth noting that there have been many

[1] Testimony of Messrs. Liebscher and Kohut, pages 401 to 407 of the Transcript.
[2] Testimony of Mr. A. Dakin, pages 425 and 426 of the Transcript.

thousands of wells drilled in Alberta and British Columbia over the past two decades, and there have been few examples of such problems in either province. It should further be noted that the Fraser Valley consortium has proposed to use a closed mud system, which provides a much higher level of protection from this risk than would be the case of the typical B.C. or Alberta well.

The consortium intends to use a non-toxic bentonite mud. If mud loss is encountered (i.e., if mud were to be lost to porous formations of coarse gravel or sandstones or other permeable material at depth) the consortium intends to use some other product rather than, or in addition to, the mud. Fibrous material such as walnut shells, chicken feathers and sawdust were mentioned by the expert witnesses as possible substitutes for or additions to the mud, all of which have been used with success in other similar situations.

In the light of the precision with which it is possible to determine if mud loss is taking place, the commission concurs with the conclusion expressed by the expert witnesses that the risk of significant contamination of groundwater from this source is remote. Further, it notes that the extra precautions being taken by the consortium in the Fraser Valley suggest that the risk of any contamination of a potable aquifer from this source is no greater, and probably far less, than previously drilled deep water wells.[3] This comparison is not to suggest that water well drilling procedures in the Fraser Valley are unsafe; far from it. The comparison is simply to permit the risk of contamination from drilling mud to be placed in the perspective of risks to the aquifer that currently exist and are currently accepted.

The second possible source of mud contamination is from a surface spill at the drilling site. The situation here would be similar to a spill of diesel fuel, gasoline, or some toxic substance at an industrial site in the valley, although the chance of a spill of any size taking place is substantially less, as the closed system proposed by the consortium will remove all but a slight chance of such a spill at the drilling sites. However there is the possibility of human error or pipe or joint failure, which could lead to a surface spill. It must be remembered that a drilling crew will be on duty twenty-four hours a day at the drilling site. Thus the possibility of such a surface spill not being discovered and cleaned up prior to any appreciable penetration of porous ground is remote in the extreme.

The third of the three possible sources of mud contamination is improper disposal of drilling mud. Whether such contamination occurs depends on the integrity of the consortium in carrying out mud disposal in accordance with their announced plan. For such an event to occur would also require highly ineffective supervision by EMPR officials. The possibility of such a combination of consortium and government failure is considered by the commission to be remote.

The commission concludes that while the chance of appreciable contamination of groundwater by reason of drilling mud exists, the possibility of such contamination occurring is unlikely in the extreme.

Contamination from Natural Gas or Brine

The second area of concern is contamination of a freshwater aquifer by gas, or by saline water from another formation moving up or alongside the drillhole and entering a freshwater aquifer.

[3] A description of the drilling of the deepest water well in the Fraser Valley, the E.P. Taylor well, was given by Mr. Liebecher and is found on pages 445 ff. of the Transcript. It is further discussed below.

There are a number of examples of such a situation, particularly in the Appalachian area of the United States.

The possibility of such a problem was discussed at considerable length by many of the technical witnesses. Prevention lies in the use of proper drilling methods, particularly in proper cementing of the well casing. These matters were discussed in some detail by Mr. Yannick Guerrini of Gaz de France,[4] and consultants Mr. Doug Ball and Mr. Bob Means, both of whom, incidentally, were witnesses requested by the Friends of the Fraser Valley. The testimony of witnesses from government, in particular those from the Alberta Energy Resources Conservation Board, Mr. John Nichol and Mr. Emil Morin, also addressed this question.

The commission also paid close attention to the views of the three groundwater experts who testified at the technical hearings, one of whom was suggested as a witness by the Friends of the Fraser Valley. While these three persons were not from or entirely familiar with the petroleum industry, their high level of professionalism in their own fields, their evident concern over protecting groundwater in the Fraser Valley, their extensive knowledge of water well drilling and subsurface geology in the Fraser Valley, and their informed comments on the issue of how cementation of a well casing should be carried out, made their testimony very valuable to the commission.

To put this risk in some perspective, it is worth noting that there have been scores of exploratory petroleum wells drilled in the valley on both the U.S. and Canadian sides of the border in past years. The number of oil and gas wells drilled is not certain: probably there have been one hundred wells drilled on the U.S. side of the border, and fifty in Canada. Most were shallow, some of which became water wells. The location of others is simply unknown. Many of these wells were drilled with what would today be considered primitive technology. Information about many of them is sketchy, but it is likely that most were not cemented at all, and it is also likely that whatever casings were used are now suffering corrosion problems. Mr. Hugh Liebscher described the situation in the following words:[5]

> *Since the mid-1920s, there have been about 10 to 20 deep exploration wells drilled by various oil companies. And, as you can appreciate, in the '20s and '30s the technology wasn't there.*
>
> *. . . There's no evidence that I'm aware of any of these early gas or oil exploration wildcat wells causing any problems to the local groundwater supplies.*

More will be said in this report about these old petroleum wells, and indeed old water wells as well. They are mentioned here only to indicate that, from the point of view of protecting Fraser Valley groundwater from interaquifer contamination, they were drilled with what is considered today to be rudimentary technology with inadequate safeguards for protecting groundwater or the environment. Despite that, there is no evidence of such wells being the source of interaquifer groundwater contamination. From this it can be inferred that the geological structure of the Fraser Valley where these wells were drilled is not similar to that of other regions of the continent, such as Appalachia, where similar drilling in the past resulted in this problem.

This lack of problem from past drilling does not mean that there is no risk from future drilling. Risk from this source, as

[4] Transcript, page 1284, and page 1302 ff.
[5] Transcript, pages 501–504.

Diagram of a Typical Gas Well

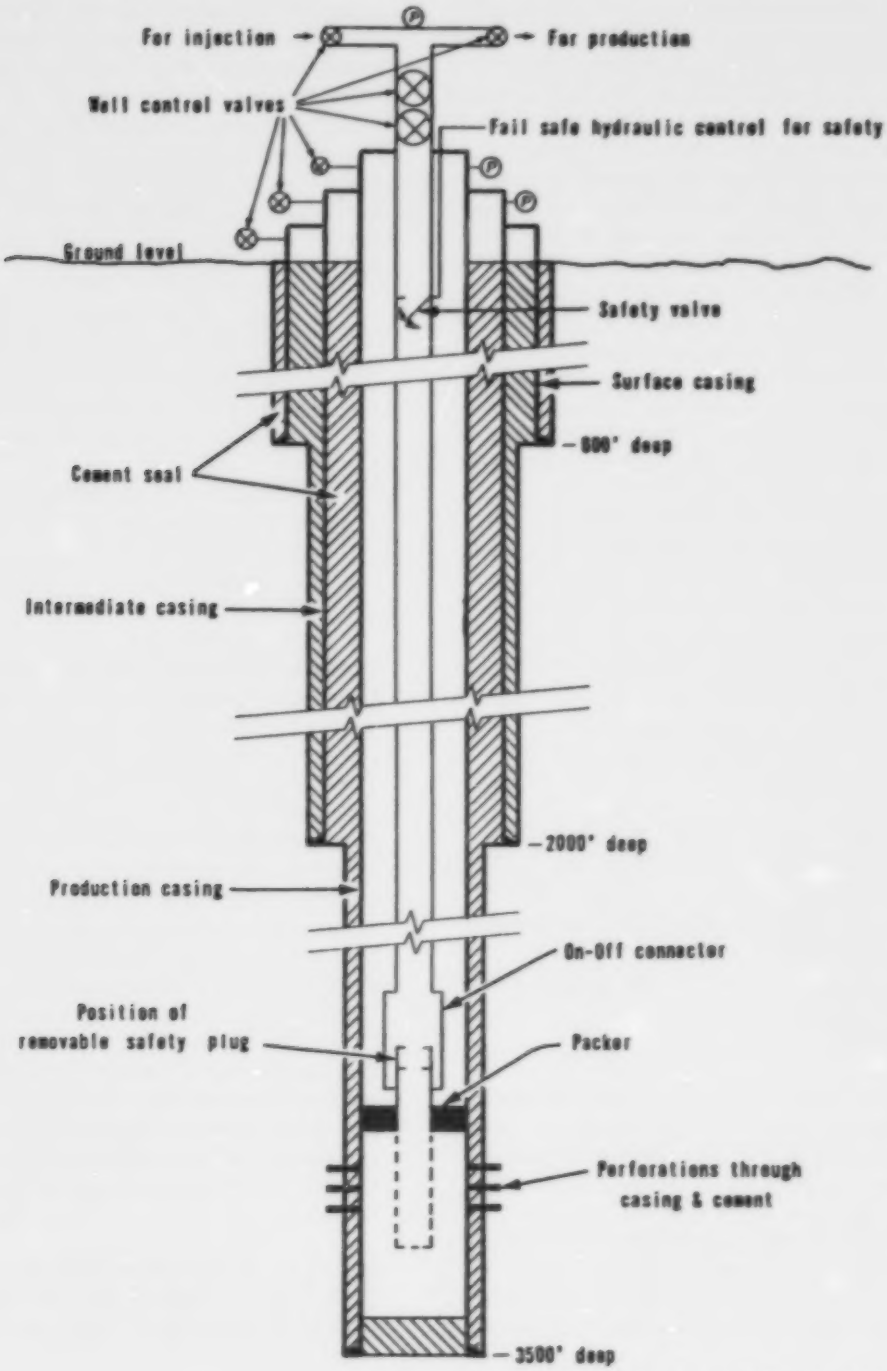

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FIGURE 14

with all other sources, cannot be reduced to zero. What it does mean is that the experience with past wells in the area in question suggests that the risk of contamination of domestic groundwater sources from saline or contaminated water in other geological formations from future drilling is low.

As noted above, proper cementing of the casing is the key to preventing this problem. A diagram of a typical gas well, showing the various cement casings and seals, is found in Figure 14.

The commission has noted the cementing proposals of the consortium, and the improvements suggested by the technical witnesses. In its opinion, if cementing is done in accordance with the best modern practices, the underground permeable zones will be effectively sealed from one another and the problem of interaquifer transfers of gas, saline water, or other contaminants will be virtually nonexistent.

It should be noted that the cementing of the well does not simply mean a tube of cement from one end to the other. Cementing of the well requires proper design and sophisticated technology. In this connection the commission notes that the Alberta regulations discussed by Mr. Morin and Mr. Nichol of the Alberta Energy Resources Conservation Board[6] require a space between the cement surrounding the surface casing and the cement surrounding any adjacent string, in order to allow any leak of gas or brine to escape to the surface through the well bore, and not through the geological formations surrounding the well, through which the well has been drilled. This is a "fail safe" provision. Any leak that might develop in the casing and cement of the lower string will be immediately noticed at the well head, without damage to the higher level potable aquifers.

Again, it must be noted that the risk on this score is not zero, and also noted that such a low risk is extremely difficult to quantify. However for rough comparison purposes, the evidence presented has led the commission to believe that the risks of all three of the proposed exploratory wells causing contamination of domestic groundwater is far less than the risk of similar contamination from the drilling of an uncemented deep water well in the valley such as the 923 feet deep E.P. Taylor well; indeed, thirty exploratory gas wells may not have the risk of a single water well of that type. This is not to say that the commission believes the E.P. Taylor well is unsafe, or was improperly drilled; quite the contrary, from the information available this well is highly unlikely to cause problems. The commission has good reason to be confident that it was drilled by competent crews using the best available technology.

This comparison is simply to point out that the drilling of that well, and all other deep water wells in the valley, also involves some risk of groundwater contamination. The method of drilling and the cementing program of the consortium, with the improvements suggested by the technical witnesses, makes the three exploratory wells under consideration in this report among the least likely of the many sources of groundwater contamination that currently exist.

Some water wells in the Fraser Valley already produce methane gas as well as water. It was reported to the commission that water well drillers, when welding pipe, have from time to time set off methane explosions. The belief that all Fraser Valley potable aquifers, and all water wells, are now without any methane contamination is incorrect.[7]

Gas can also enter an aquifer through faults in the caprock, or through migration past the spill point. Some differences between the behaviour of gas and of some other possible contaminants of potable aquifers should, however, be noted. Unlike surface contaminants affecting

[6] Transcript, page 939.
[7] Testimony of Mr. Allan Dakin, Transcript, page 509.

groundwater, gas migrates upwards through water bearing strata. In addition, water absorbs only small amounts of methane, and ingested methane is not hazardous to human health.[8]

Thus a leak of natural gas into an aquifer is likely to have limited impact on the aquifer as a whole. Instead, the rising gas is likely to seek a path to the surface and exit in a limited area. Visits to the Ancona field and the offices of the Mines and Minerals Division in Springfield, Illinois, were made in October of 1990 by the Commissioner. Government officials and officials of the Northern Illinois Gas Company were questioned about the extent of the impact of the leak in that field. He was informed that two farms are affected out of the scores in that area above that particular gas storage facility.

This is not to say that the impact of gas in the exiting zone may not have serious consequences, and affect many people. The Williamsburg, Michigan, incident of April 1973 affected the whole community, and some four hundred people were required to evacuate their homes for periods of two weeks to six months.[9] The point to be noted is that rising gas will eventually reach the surface and vent off, and the aquifer in time will be usable again, albeit with lower quality of water for some time. Further, it is generally possible to drill and recapture such gas above its escape point, thus keeping it out of the aquifer entirely, or limiting the area of the aquifer in which it occurs. At the present time, for instance, Northern Illinois Natural Gas is drilling near a property experiencing problems at Ancona, in the hope of intercepting the gas that is now routing itself to the surface through a well. Based on past experience of other companies, Northern Illinois officials are confident that this recapture plan will be successful.

The Herscher underground natural gas storage field, also in Illinois, has carried out a similar but much larger scale program of drilling to recapture leaked gas from above the faulted caprock of its main natural gas storage field. This interception, recapture and reinjection of gas was described by witnesses at the technical hearings as successful.[10] The Laclede Gas Company dealt with a similar problem some years ago in Missouri in much the same way.[11]

RECOMMENDATION 7

Storage Facility Strata

That any underground natural gas storage facility established in the Fraser Valley be at depths which provide at least one impermeable stratum above the gas storage zone to act as a catchment area in case of gas migration.

The recovery of an aquifer through which gas has escaped may well take a long time and in the interim cause inconvenience and expense, but it will eventually occur. Gas has vented naturally from underground formations through aquifers over geologic time, in many parts of the world. By contrast, the many hundreds of abandoned fuel-oil tanks in the Fraser Valley, many of which

[8] This is discussed in the chapter of this report on Health and Safety.

[9] The reason for the evacuation at Williamsburg was the fear of fire, which incidentally did not occur. The Williamsburg accident did not involve an underground natural gas storage facility. This incident was the subject of an investigation by the state, on which there is a published report "An Analysis of the Amoco State Whitewater "E" 1-22 Well as the Cause of the Natural Gas Eruptions at Williamsburg and Acme, Michigan in April 1973," Moody and Associates, Harrisburg, Pennsylvania, and Columbus, Ohio, October 1974.

[10] Testimony of Mr. Howard Griffith, Transcript, page 1235 and of Messrs. Ball and Means, page 1494.

[11] This case had an unusual twist — the farmer through whose water well the gas was escaping was not pleased to have the situation rectified, as he was heating his pig barn with the gas, at no cost to himself.

at present are leaking, or which can be expected to leak in the near future, or the pesticides and herbicides and other surface contaminants which are entering underground aquifers from surface runoff, are altering the quality of the groundwater in quite a different manner. This contamination will not find its way out of an aquifer naturally, and at a certain point may render the waters useless for any domestic, agricultural or industrial purpose for literally millennia to come.

The leaking storage tank problem is not minor. There are roughly some 50,000 fuel storage tanks in British Columbia of which half may well be in the Lower Mainland. Many of these have been abandoned, and a surprising number (approximately 5%)[12] were found by a federal study of tanks on the North Shore to be leaking. It may take twenty or thirty years for the leaking fluid to turn up in someone's well, and by then the cost of cleaning up the contaminated soil may well cost in the hundreds of thousands, if not tens of millions of dollars. This situation has already been forcefully brought to the attention of the Province in the case of the Expo lands. There is no chance of removing the contaminant that has reached and entered the groundwater.

When discussing contamination of groundwater and legislation to protect it, the issue of soil contamination inevitably occurs. The leaking fuel oil tank, or leaking gasoline storage problem described above spreads downward, sideways, and ultimately reaches the aquifer. In so doing, soil contamination may be extensive. Further, efforts to remove the contaminating liquid that has already leaked from the abandoned and defective storage tank involves removal of the soil through which it is percolating to the aquifer below. Once it reaches the aquifer there may also be residual contamination of the sands or other permeable rock of which the aquifer is composed. Thus developing a program of groundwater protection, and a legal framework for protection of the groundwater, inevitably involves toxic soil issues as well as groundwater contamination issues.

It is beyond the scope of this report to enter into this area in any greater depth. In any event, the task of examining the problems of polluted soils and toxic real estate in this province and developing a draft statute for handling the issues involved was done in September of 1990 by Mr. James Russell and Mr. William Andrews of the West Coast Environmental Law Research Foundation. A companion volume on toxic real estate liability, prepared by Mr. Waldemar Braul assisted by Ms. Ann Hillyer, discusses liability issues. This important work was sponsored as a public service by the Real Estate Foundation of British Columbia, and by the Law Foundation of British Columbia. The draft statute and companion liability document have been printed and widely distributed.

The commission recommends that these documents and the draft statute be examined carefully by the government, that the proposed groundwater legislation and the draft toxic real estate legislation be brought into conformity, and that draft government legislation to protect groundwater and deal with the issues of toxic real estate be brought before the Legislature without delay.

A report in the Vancouver Sun of 5 October 1990 (page A1), a month after the commission's technical hearings ended, quotes studies done by Agriculture Canada to the effect that the herbicide Dinoseb was found in 11 out of 54 wells tested, two of which serve houses in the Aldergrove area. Health and Welfare Canada states that Dinoseb

> *[I]ndicates appreciable risk for birth defects, cataract formation, and male reproductive effects, even with full protective clothing . . .*

The use of Dinoseb has been banned in most provinces of Canada. However

[12] Testimony of Allan Dakin, Transcript, page 420.

because its elimination in B.C. would impact the local agricultural economy, it is still in use in this province in the production of peas, beans and raspberries.

It is well beyond the terms of reference of this commission to comment on the wisdom of this decision, which may be entirely correct. However if Dinoseb is found in water wells of the Fraser Valley, there is a possibility that the chemical is entering these wells through groundwater which is already contaminated with the product; in which case there is in all probability no possible way of decontaminating the water underground. The Dinoseb example illustrates the wellfounded basis of the concerns over existing chemical contamination of Fraser Valley groundwater expressed by experts at the technical hearings.

The summary observations of Mr. Allan Dakin, found at pages 518 to 521 of the transcript, clearly states the case in this regard. He said:

> *. . . the groundwater resources in the Fraser Valley are very extensive, and very valuable, and we strongly recommend that every effort be made to ensure that the quality of the groundwater in the Valley be preserved.*
>
> *It doesn't matter whether it's this particular drilling program. Any other activity, we have to put in the same perspective.*
>
> *. . . I believe that when you put this into perspective and compare it with other sources of contaminants . . . there's more chance that these other activities will continue to contaminate aquifers, and I think there's a relatively low chance of . . . this proposed gas storage and test drilling programme affecting the groundwater.*

Mr. Hugh Liebscher agreed with Mr. Dakin's assessment that there are now existing sources of contamination which might exceed those of exploratory drilling.[13]

The commission concludes, therefore, that if proper procedures for drilling and cementing of the casing take place, the chance of appreciable contamination[14] to the potable aquifers from the proposed exploratory drilling program is remote. It also concludes that if this remote chance occurred, the possibility of interception of the escaping gas in a higher geological formation or catchment area is high. However in the unlikely event of interception at an overlying impermeable stratum being unsuccessful, it concludes that the resulting damage to potable groundwater is highly unlikely to be widespread, or long term. Finally it concludes that the risk of contamination of Fraser Valley groundwater at the present time from sources other than possible exploratory petroleum drilling is high, and is increasing.

The paragraph above makes it clear that the risk to groundwater of exploratory drilling is not zero. Unfortunately, as those who deal with risk statistics know, extremely low probability situations are impossible to quantify accurately. A figure can be given, but such figures are essentially guesses, totally dependent on a large number of factors, all of which are themselves subject to substantial variation. Thus it is not possible for the commission to place a reliable figure on the risk of appreciable damage to groundwater from exploratory petroleum drilling in the Fraser Valley. Whether the chance of appreciable damage is one in fifty thousand, or whether it is one in four hundred thousand, is simply not possible to determine.

One technique used in such circumstances is the Delphi Method, which essentially

[13] Transcript, page 523.

[14] In this discussion, temporary turbidity by reason of drilling on seismic activity is not considered to be appreciable contamination. Such turbidity can also take place by reason of drilling other water wells, or by the passage of heavy vehicles. Temporary turbidity is very different from long term damage to an aquifer.

asks for the opinions of a number of experts in a series of questions, and averages the results. The commission believes that the use of that process would probably put the risk near the lower of the two figures given above. By contrast, the commission expects the risk of appreciable contamination of groundwater from other sources to be very different. In fact, contamination from these sources is no longer a risk statistic; it is taking place now.

Protection of Groundwater and Other Water Resources

The Province has several statutes and regulations which directly or indirectly address the potential for contamination of water supplies by petroleum exploration operations, including the *Petroleum and Natural Gas Act*, the *Drilling and Production Regulation*, the *Geophysical Exploration Regulation*, the *Environment Management Act* and the *Waste Management Act*. The federal *Fisheries Act* is also relevant.

However, there is no general, statutorily enunciated policy of protecting the province's water resources, much less a single comprehensive statute dealing with groundwater or water resources in general. The commission was impressed by the testimony of expert witnesses Dakin, Kohut and Liebscher, all of whom pointed out the need for groundwater protection legislation. The following recommendations address the need for statutory and regulatory reform in this area.

RECOMMENDATION 8

Enactment of a Uniform Groundwater Conservation Act

That a single groundwater conservation statute be enacted and related regulations be drawn up. Such a statute would address water quality standards, aquifer classification, the regulation of both point and non-point sources of pollution, and related administrative procedures.

RECOMMENDATION 9

Toxic Soil

That toxic soil legislation based on the proposals contained in* Law Reform for Sustainable Development *of the British Columbia Branch of the Canadian Bar Association be enacted.

RECOMMENDATION 10

Declaration of Policy of Balanced Approach to Protection of the Province's Waters

That a policy of balanced protection of the Province's waters be established by means of a preamble to the* Groundwater Conservation Act *described in Recommendation #8, the* Environment Management Act, *and other appropriate statutes. The preamble might be in the following form:

> ***The purpose of this Act is to ensure the purity of all waters of the Province consistent with public health and public enjoyment thereof, the propagation and protection of wildlife, birds, game, fish and other aquatic life, and the industrial development of the Province, and to that end require the use of all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the Province.***

RECOMMENDATION 11

Environmental Management Plan for Water Resources in the Fraser Valley

That in the event that the Recommendation above is not adopted, the Minister of Environment, under the Environment Management Act, *s. 2(f)(iv), issue an environmental management plan for water resource management in the Fraser Valley.*

RECOMMENDATION 12

Division Responsibility to Remedy Defective Old Abandoned Wells

That the Petroleum and Natural Gas Act *and the* Drilling and Production Regulation *be amended to give the division the responsibility, authority and power to plug, replug, clean, or otherwise repair old test holes and petroleum exploration wells, and water wells, that appear to be a source or potential source of pollution, and that such a program be undertaken on a priority basis.*

RECOMMENDATION 13

Underground Injection Control Program

That an underground injection control program be implemented, classifying wells and groundwater aquifers according to their purpose and identifying the substances that may be injected into them.

The possibility of earthquakes adversely affecting potential gas facilities, or adversely affecting the exploratory drilling program, was a frequently expressed concern at the public meetings of the commission. This concern was addressed in depth at the technical hearings at the end of August. Dr. Dieter Weichert, Director of the Pacific Geoscience Center at Sidney, B.C., Dr. Liam Finn, professor of civil engineering at UBC and a consulting specialist in earthquake risks, and Dr. Steve Palmer of the Washington State Division of Geology and Earth Resources, a specialist in Puget Sound earthquake hazards, testified. In addition, Drs. Finn and Palmer prepared papers for the commission, Exhibits T-27 and T-28, as did Douglas G. Honegger of the EQE Engineering Company of Los Angeles, consultants to the consortium (Exhibit T-29). The participation of Dr. Finn was suggested to the commission by the Friends of the Fraser Valley. The commission is also grateful for the helpful comments of Dr. James Monger of the Vancouver office of the Geological Survey of Canada, and Mr. Joseph Molloy of the Atomic Energy Control Board, Ottawa.

The risks of earthquakes to gas facilities can be divided into three categories: first to facilities above ground, second to horizontal pipelines in the ground, and third, to the actual production facilities, the vertical (and deviated) wells in the ground. A further and highly unusual possibility, that the injection of gas underground and the pressure that results may induce microseismic effects, will be considered separately.

Above Ground Facilities

Above ground risks to gas facility structures are in large part similar to those of other industrial structures. There is additional risk by reason of the possibility of fire, or explosion of gas, which requires the incorporation in the design of automatic shutdown equipment. The provisions of the National Building Code of Canada deal with earthquake risk, as do the provisions of its American counterpart, the Uniform Building Code.

Properly designed structures with effective shutdown equipment can reduce earthquake risks to above ground structures to very low levels. Nuclear power facilities are designed to withstand high levels of possible earthquake activity. The Canadian Standards Association general requirements for nuclear reactors in Canada, for example, stipulate that reactors be designed to withstand a one in a thousand year earthquake, to shut down, and be back producing power within an hour. Such reactors are also required to be designed to withstand a one in ten thousand year earthquake, and to shut down without significant release of radiation.[1]

Whether such design standards are adequate is not a subject for this report; what is significant is the ability of engineers and designers to create virtually earthquake proof systems. What can be done for nuclear power can also be done for other power sources. Above ground natural gas facilities can similarly be designed to have low risk from earthquake damage.[2] Such design and subsequent construction of course has a price, and an appropriate level of protection is essentially a dollars and cents decision. The commission suggests that the appropriate standard to adopt for natural gas facilities should be the standard that provides the same protection as B.C. Hydro is currently employing.

[1] Canadian Standards Association: Standard CAN3-289.1, Seismic Qualifications of CANDU Nuclear Power Reactors.
[2] Testimony of Drs. Steve Palmer and Liam Finn, Transcript, page 567.

Underground Facilities

With respect to gas fields and underground natural gas storage facilities, Dr. Finn's paper described the situation in the following terms:[3]

> *There is little data on the adverse performance of gas fields and associated wells during earthquakes. Known gas fields which have been subjected to earthquake loading are in southern California, Niigata, Japan, and in the Caucasus region of the Soviet Union. Reports on these earthquakes are silent on the performance of the gas fields, presumably because nothing happened.*
>
> *The absence of damage in these fields is reassuring, but cannot be understood to preclude damage in all fields. Critical information on these fields is not generally available. Key factors which control the performance of the field during a given earthquake include the depth of the formations storing the gas, the degree of over-pressuring, and the proximity of active faults.*
>
> *Some of the public worry about the possibility of large scale uncontrolled release of gas into the atmosphere during an earthquake with the possibility of fire and/or explosion. For this to occur a major fault would have to traverse the gas formations and exit the ground surface, or a general fracturing of the overburden would have to occur. These events are extremely unlikely except possibly in very shallow formations.*
>
> . . .
>
> *It should be clear, therefore, that the depth of storage is a key factor in the safe performance of a gas field during an earthquake.*

Pipeline Systems

More information is available on the damage to horizontal piping systems from earthquakes, mainly because such damage is more common. This damage typically occurs in older cast iron pipe, and frequently at junctions of pipe and valves or other structures, where the vibrations of the pipe are checked by a less resilient structure. Modern welded steel pipe, and modern design, can minimize much of the risk, but there is still some remaining concern. It should be noted that this risk currently exists in the Fraser Valley with the Westcoast transmission system, and the B.C. Gas distribution system. Testimony at the hearings[4] about the Niigata earthquake of 1964 and the Nehan Kichubo earthquake of 1984 indicated that the small feeder lines going to homes and businesses are more likely to experience damage than the main lines, which had few problems. Flexible distribution piping introduced in recent years has greatly reduced this risk.

As mentioned elsewhere in this report, the amount of new piping that would be required for an underground gas storage system or for new production wells in the valley is not high, and the increase to the existing risk that gas storage might present would be marginal. If, however, extensive gas deposits were found in the Fraser Valley the situation would change; establishing a gathering system to link a large number of producing wells to a transmission system would inevitably substantially increase the amount of horizontal pipe in the valley. Pressures of such a gathering system would likely be well below those of the Westcoast pipeline, or of pipelines to and from a gas storage facility. Further, the diameter of the gathering system pipes would in all likelihood be small, and the lines flexible. This would suggest that while the break of a pipeline might increase, the gathering pipeline systems would have less

[3] Exhibit T-28, page 2.
[4] Transcript, page 570.

potential for gas losses than would the higher pressure, larger diameter, pipe. It must be remembered that unlike the distribution system piping, gathering and transmission systems have far less proximity to populations and inhabited buildings.

The Liquefaction Problem

The paragraphs above deal with a pipeline in the ground which maintains its integrity during the earthquake, and where the pipe is flexed back and forth, or up and down, or a combination of the two. The pipe moves with the ground, and rarely fractures except at valves, fittings, or other points at which it connects with a less flexible structure. Liquefaction of ground during an earthquake presents a more difficult situation for a pipeline. Liquefaction is a major potential seismic hazard in Richmond and parts of Delta and Ladner.

The phenomenon of liquefaction was described by Dr. Finn as follows:[5]

> *. . . if the ground is sandy, fairly loose and contains water, it is a prime candidate for liquefaction during an earthquake.*
>
> *That means that when the ground is shaken, pressure develops in the water, and the loose ground tends to try to compact. The grains of sand want to get closer together. They can't do that unless the water can escape, because it is in a fixed volume, and unless something goes out, the grains of sand can't get closer together.*
>
> *If the water cannot escape fast enough, then the weight of the ground is transferred to the water, and it builds up a high pressure in the water. It then reduces the friction between the grains of sand, and the sand essentially has no strength, because it depends on that friction for strength.*
>
> *. . . if the sand loses its strength, it behaves like a liquid, and hence the term liquefaction.*

With the exception of part of Delta, the rest of the Fraser Valley is served by the B.C. Gas distribution system. In the case of an earthquake and soil liquefaction, it seems probable that this extensive existing distribution system would pose far greater risks than the risks from earthquakes in other areas served by B.C. Gas. Pipeline studies were done in parts of this area for the southern route of the natural gas pipeline to Vancouver Island[6] Various methods of reducing risk, such as routing a pipeline through the least populated areas, and decreasing the spacing of shut off-valves on the pipeline combined with ground motion sensors to activate such valves, will reduce but not eliminate risks from this source.[7] Were a new large diameter gas pipeline to be constructed in this area, further soil studies of liquefaction, and the effects of liquefaction on a pipeline during a major earthquake would be required.

RECOMMENDATION 14

Liquefaction Risk Assessment

That liquefaction-related earthquake risks to existing pipelines and other energy facilities in the Fraser Valley be assessed.

The Experience of California

The experience of California's oil and gas fields during past earthquakes suggests that the risk of damage to the producing field or storage facility underground is not

[5] Transcript, page 572.
[6] The route which was not chosen; testimony of Dr. Liam Finn, Transcript, page 575.
[7] Testimony of Dr. S. Palmer, Transcript, page 579.

great. There have been a number of recent earthquakes centered near oil and gas fields, particularly the San Fernando earthquake of 1971 (magnitude 6.6 on the Richter scale) and the 1983 Whittier Narrows earthquake (magnitude 6.1). In each case there were two gas storage fields located within 10 kilometres of the epicentre; however no damage to these facilities was reported.

Similarly the 1952 Kern County earthquake (magnitude 7.4 on the Richter scale) had gas fields within ten kilometres of the epicentre. The area within 40 kilometres of the epicentre includes the San Joaquin Valley, one of the most prolific oil and gas areas of the United States. These gas and oil fields experienced very severe ground motion (0.35 G or greater). Damage occurred, particularly to structures. Fourteen people were injured, mostly from falling buildings; apparently none were injured from gas, wells, or other gas equipment or fire from gas. Some older wells collapsed; it was subsequently determined that the casing of these wells was badly corroded.[8] Another earthquake struck the San Joaquin Valley in May of 1983, at Coalinga. Here the force was 0.6 G, (or 60% of the acceleration of gravity), and the facilities were virtually over the fault line.

Dr. Palmer's conclusion on the effect of these earthquakes was as follows:[9]

> *These two earthquakes provided a rigorous test of the vulnerability of nearby oil field facilities to strong ground motion. Behavior of these facilities was good, especially considering the likelihood that little seismic design was incorporated into most of the older structures . . . Also important was the apparent lack of wellbore damage associated with slip along the primary rupture, or along subsidiary faults and bedding planes.*

At the technical hearings Dr. Palmer elaborated on his written remarks. He added:[10]

> *I think one thing probably to keep in perspective with these oil fields, as I say, they are very old. The initial development started at the turn of the century . . . a lot of the piping, collecting pipeline, exiting these wells was in fact cast iron pipe as opposed to welded steel. Cast iron tends to have much poorer performance . . . during an earthquake. These facilities, especially in the Kern County earthquake, probably had very little if any seismic design, or seismic input into the design of the structures.*

Subsidence Problems

The greatest risk of damage appears to be to wellhead facilities or to the near surface casing by reason of ground subsidence. Such subsidence has been found in the Long Beach area of California and in some parts of Eastern Europe and in Venezuela. Subsidence in these areas has been the combined result of an earthquake in areas where previous withdrawals of gas or oil have taken place, and where there has been no water injection to preserve the pressure in the porous rock formations. This situation is not present in the Fraser Valley. In the event that production took place here, the problem could be prevented in the future by maintaining field pressure by water injection.

On the subject of underground damage to the wells themselves, Mr. Honnegger's paper is of note. He writes:[11]

> *Several conditions must exist for fault motions to impact a well and pose a threat to life and safety. At a minimum, the well must cross an*

[8] Exhibit T-29, page 2 and testimony of Dr. Palmer, Transcript, page 586.
[9] Exhibit T-27, page 3.
[10] Transcript, page 588.
[11] Exhibit T-29, page 2.

> *active fault, the earthquake must be generated on a fault crossed by the well, the fault rupture must result in relative fault movement at the point where the well intersects the fault and the fault dislocation of the well must lead to a release of gas. The chances for all conditions being met is extremely remote. A small likelihood of occurrence and a lack of any historical problems are possible factors for the lack of past concern for this hypothesized situation.*

Dr. Finn in his paper writes:[12]

> *. . . it is my understanding that there are no active faults in the area (of the Fraser Valley).*

Dr. Weichert's testimony was similar:[13]

> *. . . as I pointed out earlier, much of their seismicity is on land, along the San Andreas Fault, while much of the equivalent seismicity here is offshore, way offshore. We have no San Andreas Fault, we have no surface faults. We may have some very shallow seismicity, as I indicated earlier. None of them seems to have broken the surface, as is almost the rule in California.*

The possibility of underground damage to a well or wellhead from an earthquake in the Fraser Valley, whether a production well or a withdrawal/injection well of an underground gas storage facility, thus appears to be slight.

Induced Seismicity

The final concern over seismic effects is whether underground natural gas storage, or gas production, might itself cause or trigger microseismic effects, through gas injection or withdrawal.

One of the best known examples of such a microseismic effect from withdrawal is the Wilmington field in the Long Beach, California area. This is a very large oil field, which has been exploited extensively since the 1930s. Soon after production began, subsidence was noticed. By 1950 this had reached 5 metres, and twenty years later had doubled to 10 metres. The cause of the subsidence was the withdrawal of oil. The resulting reduction of fluid pressure resulted in a greater weight of overburden on the sandstone layer of the reservoir, which compacted under the pressure. This led to stresses on the weak shale rock strata above, and to five small, localized, earthquakes between 1947 and 1961, registering from 2.4 to 3.3 on the Richter scale. In turn this put 185 wells out of production. Subsidence stopped with injection of water into the formation.[14]

Similar, although far less certain and well documented examples of induced seismicity may have taken place in southwestern France, at the Lacq field, in the early eighties, at two west Texas fields, Ward Estes North and Codgell, and at the south Texas fields of Imogene and Flashing.

The best known example of seismicity induced by injection occurred at the Rocky Mountain arsenal near Denver, Colorado, where disposal of waste fluids took place by way of injection into underground reservoirs. There was no withdrawal of fluid to compensate for the injected material. An induced earthquake occurred. The local effect measured 5.5 on the Richter scale. There have been no documented examples of induced seismic effects from underground gas storage facilities, although in at least one Italian field concern over the possibility has led to extensive deployment of instruments. The commission's inquiries in Italy indicate that results to date have not provided evidence that links the gas

[12] Exhibit T-28, page 2.
[13] Transcript, page 553. Further discussion of the issue by Dr. Weichert and Dr. Finn occurs at pages 595 and 596.
[14] Dr. S. Palmer, Transcript, page 602.

storage facility in question with seismic activity. In short, induced microseismicity is rare. Where it may have occurred, it does not appear to have caused substantial difficulties. Non-induced seismic activity is a far more important matter of concern.

As the three paragraphs immediately above suggest, information on induced microseismicity elsewhere in the world is slight, and what is available does not provide any serious basis for concern in the event of the establishment of an underground natural gas storage facility in the Fraser Valley. Before it is possible for a more detailed examination of whether microseismicity might occur were a facility to be established, and whether, if it did occur, it could pose problems, it is necessary to have considerably more geological data of the properties of the rock formations underground. Exploratory drilling is the only practical means of obtaining such information, and thus further consideration of this issue should await the results of such drilling in the Fraser Valley, assuming that such drilling is allowed to proceed by the government, and assuming that such exploratory drilling leads to a proposal from B.C. Gas to establish a natural gas storage facility. As Dr. Palmer observed at the technical hearings:[15]

> *The first thing you need to understand, of course, is the actual properties to the rocks that you propose for a reservoir. And those really, literally, can't be measured without drilling.*

Conclusions

The overall conclusion on earthquake risk is that the possibility of damage to the current transmission system and the distribution system exists at the present time. Were there a major earthquake, damage to the distribution system, and some escape of gas, could be expected. Damage to the transmission system is less likely, but possible at compressor stations and at valves. In both cases, were such releases of gas accompanied by damage to nearby electrical systems, fire might result.

The earthquake risk to production wells and facilities, were gas to be found and exploited in the Fraser Valley, likely would be to horizontal pipelines and would amount to only a fraction of the risk from present distribution systems. By reason of improved technology since the Westcoast transmission system was built some thirty years ago, the risk of damage to the new horizontal pipe can be expected to be less than the existing risk posed by the Westcoast system, although this does not mean that the commission is of the view that the earthquake risk of Westcoast's facilities is high. The risk to production wells would be very slight.

Underground gas storage facilities and companion wellheads are the least likely component of a natural gas system to suffer earthquake damage. However, were such damage to occur, pipelines at the compressor station would be the most likely source of problem. The risk of damage to injection/withdrawal wells is very low. The risk of gas venting to the surface from the storage facility through a fissure caused by an earthquake appears remote in the extreme.

It should be noted that good design and careful construction techniques, which have been developed in the earthquake prone petroleum production areas of California, particularly along the San Andreas Fault, can greatly reduce earthquake risks to natural gas facilities. With modern design and construction, the risk to human life or health, or the risk of human injury, from earthquake induced damage to natural gas production, storage, and delivery systems is very slight. Finally it should be noted that the Lower Mainland, including virtually all of

[15] Transcript, page 603.

the populated portions of the Fraser Valley, have natural gas distribution systems already in place, and in the event of a major earthquake, these distribution lines are likely the most hazardous component of the overall system to human life and safety. The extra risk posed by underground natural gas storage, or by production facilities, would be, by contrast, negligible.

General

There are a number of health and safety issues associated with exploratory drilling. The commission has not considered these issues as they apply to those working the drilling rigs, but only with respect to those who reside nearby. In the opinion of the commission, the Workers Compensation Board, the Ministry of Labour and Consumer Services, and the Ministry of Energy, Mines and Petroleum Resources are fully familiar with the health and safety aspects for those working on the drilling sites. We are also fortunate in British Columbia to be able to take advantage of the experience of our sister province of Alberta, one of the leading jurisdictions in the world in this regard.

Health and safety issues were frequently raised at public meetings. The risk of a blowout and subsequent fire, or poisonous sour gas emissions, were major concerns of many participants. Much of the literature and information activities of the Fraser Valley Gas Project consortium also addressed these issues.

There are other health and safety risks apart from those that stem from a blowout. Concerns expressed at public meetings ranged from concern over the psychological impact of a resident being informed of an evacuation plan and living under such a plan for the period of the drilling, to the physical effect of lack of sleep by reason of the noise of drilling at night from a nearby drill site, to the toxic effect of methane in drinking water.

The human health and safety impacts of the petroleum exploration process and an exposure to natural gas were carefully examined by the commission. The commission found the health risks from petroleum exploration to be occupational rather than public in nature. In the history of petroleum exploration in Western Canada, any deaths resulting from the exploration process have occurred on the lease area, and not in surrounding residential areas. As well, the escape into the open air of sweet, dry natural gas (the type of gas considered to be present in the Fraser Valley) is only very rarely a hazardous event. Natural gas is non-toxic. It is lighter than air. It rises into the atmosphere when released.

Only where hydrogen sulphide (H_2S or sour gas) is accidentally released into the environment does petroleum exploration and drilling pose a threat to public health and safety. As discussed later in Chapter 15, sour gas has never been found in the Fraser Valley area, and geologists believe that the geological formations which exist in the area make it highly unlikely for sour gas to be present. The likelihood of such a blowout, moreover, is very remote.

This chapter examines a number of public concerns related to the health and safety impacts of petroleum exploration and natural gas. These are the frequency of well blowouts, the physical materials projected as a result of a blowout, the effects of human exposure to natural gas, the potential for explosion or asphyxiation resulting from the accumulation of natural gas, the health effects of natural gas in drinking water, the recent issue of radium in oilfields and the effects of human exposure to hydrogen sulphide or sour gas. In addition the public concerns over psychological impacts of petroleum

exploration are addressed, as are the health aspects of noise. Issues associated with the Emergency Response Plan, the positive health impacts of natural gas use, and the physical security of petroleum facilities are also discussed.

Before considering these individual concerns, it is useful to put the risks of drilling in some context. Many serious accidents within the industry have been brought up at commission hearings. Through reports of these accidents, the questioning of expert witnesses, and visits to the sites by commission staff, these have been looked into for the lessons that they may offer to British Columbia. However the industry is itself a very large and important one, and these accidents must be put in the perspective of time and scale — not to mention geology and geography. This is particularly important when a commission of this sort is charged with determining not what was the cause of an accident at some past date, such as the Commission of Inquiry into the Save-on-Foods roof collapse in Burnaby,[1] but rather, what are the risks and benefits of proposed industrial activity in the future. Anecdotal histories of accidents are important, but their usefulness is much greater when placed in the context of the industry today.

In this connection, the commission notes that improvements in the safety of the industry, and thus reductions in risk, have been the trend of the past few years and, indeed, decades. Time after time at the technical hearings those familiar with underground natural gas storage mentioned that the safety record of the industry today is a far cry from what it was in the late fifties, or sixties, or even the seventies. To take an example from another field, it would be misleading to give examples of heart transplant failures in the sixties in order to obtain an understanding of the risks of such operations today. The same is true of the petroleum industry. Professional engineers, like doctors, have advanced technology dramatically.

The commission notes that many past accidents have been described as the result of human error. In this the industry is not unique; many other industrial accidents are similarly described. However some industries have been more vigorous than others in taking steps to reduce human error accidents, and the petroleum industry is one of these.

The causes of this decline are various, but two in particular stand out, namely the constantly improving technology of petroleum exploration and well drilling, and the improvement of crew training.

It is unnecessary in this report to detail the history of technological improvements over the past forty years; some small, some large, some resulting from the introduction of computers and other sophisticated electronic equipment, some simply the improvement of the tools used by the crews. Some are the results of long years of work by scientists, others by contrast result from the trial and error experience of petroleum field roughnecks on the rigs. The result is a greatly improved technology over what it was in years past.

The second item mentioned is crew training and improved industry procedures. Again, it is unnecessary to detail the efforts made by the industry to improve this aspect of its operations, and why the industry has been so much more effective in this regard than some other industries. Suffice to say that it has taken place, and as a result the number of error induced accidents has declined.

[1] Province of British Columbia, *Report of the Commission Inquiry, Station Square Development*, Dan J. Closkey, Commissioner, 1988.

The bottom line of this process is a much less risky industry. Some quick comparisons between those who work in the petroleum industry with those who work elsewhere show this in relative terms. For example, the Workers Compensation Board levies charges on companies in various industries. These charges are calculated in accordance with the accident rates of those industries. Companies employing petroleum exploration and development workers are charged virtually the same rate as companies that employ farm workers ($2.55 for petroleum, $2.40 for farming). Construction workers, by contrast, require premium payments of $5.36, double that of petroleum industry workers. Truck drivers require $8.51, more than triple the premium for workers in the exploration and development end of the petroleum industry.

Blowouts

Frequency

Perhaps the most reliable information on the possibility of blowouts comes from historical experience. A study prepared for the U.S. Department of the Interior[2] examined the incidence of blowouts in Alberta for the period 1960 to 1980. The study authors concluded there were 2.4 blowouts per thousand wells in the entire period from 1960 to 1980, and only 1.6 blowouts per thousand wells in the last half of the study period, from 1970 to 1980. The analysis of the causes of blowouts during this period suggests that the decline in frequency in Alberta (as well as other jurisdictions) has probably continued for the decade that ended last month. The causes for this decline are outlined in the paragraphs above.

The American study from which these figures are based was supported by the testimony before the commission by the Fraser Valley Gas Project consortium, the Alberta Energy Resources Conservation Board, and by the Ministry of Energy, Mines and Petroleum Resources. Blowouts are not common events.

Conoco, the member of the Fraser Valley Project consortium which will be carrying out the drilling program through contractors, claims to have the best safety record of any major petroleum company in the world.[3] It has informed the commission that it has not had a blowout at any of the hundreds of wells it has drilled in North America during the past two decades. It has had wide experience of selecting drilling contractors in B.C. and Alberta, experience that it is confident will allow it to chose the safest and most reliable that are available. The control procedures they have outlined to the commission for the Fraser Valley project are stringent. Further, the consortium has committed itself to a high level of supervision from the Fraser Valley Gas Project office of the drilling contractor or contractors. Finally, EMPR officials will in turn be supervising the project closely.

The factors mentioned above are very important. Perhaps most important is the record of Conoco, the very evident corporate pride in this record, and the fact that a wealthy and powerful company can be expected to be successful in inculcating the corporate culture into the work habits of its employees and contractors. Virtually every blowout accident referred to in the commission's inquiry was the result, at one stage or another or cumulatively, of human error.

Contractors and crews in the drilling field vary in their abilities and in their attitudes to procedures and to safety. This

[2] D.W. Layton, R.T. Cederwall, Y.E. Ricker, J.H. Shinn, K.D. O'Banion, "Accidental Releases of Sour Gas From Wells and Collection Pipelines in the Overthrust Belt: Calculating and Assessing Potential Health and Environmental Risks", Lawrence Livermore National Laboratory, University of California, prepared for the U.S. Department of the Interior, April, 1983, pages 23-24.

[3] Fraser Valley Gas Project Summation, page 24, in the Commission Record. Based on American Petroleum Institute statistics.

is, of course, true of every other field of human endeavor. What is critical here is not that abilities differ, but that Conoco has the money, the experience and the wish to obtain the services of the best operators.

The 1973 Williamsburg incident is a case in point. The Commissioner and the Commissioner's Technical Advisor, Mr. Tony Fogarassy, visited the site of that accident in July of 1990, in the company of Mr. Mark Nida, an engineer with the Petroleum Engineering Section of the Michigan Public Service Commission, who later testified at the technical hearings.[4] Even seventeen years after the accident, and even after a professional career observing the failings and correcting the mistakes of other petroleum operators in the state, Mr. Nida's voice reflected wonder and disbelief as he described the errors made by the drilling foreman and crew whose decisions resulted in that accident. A corporate culture that places a high value on safety and proper procedures is not likely to have such employees.

At the technical hearings, Mr. Nida stated that following the Williamsburg incident, the State of Michigan introduced Order 2-73, which improved the regulations governing petroleum exploration in the state. He also stated that since 1973, there have been no subsurface blowouts similar to the Williamsburg blowout.[5]

The second issue mentioned above is supervision by the consortium. The Commissioner is satisfied that the publicity that has surrounded the Fraser Valley Gas Project consortium's request to drill in the area is the best guarantee that the consortium will watch the drilling contractor very closely, and that it will be eager to provide immediately whatever professional or technical backup at whatever cost that might be of assistance to the contractor, whether from industry consultants in Alberta, or from universities in or out of Canada. Given the publicity, a failure to carry out such supervision would no doubt be the end of the reputations of Conoco, B.C. Gas and Dynamic as responsible corporate citizens of this province and country, and would seriously damage public confidence in the industry as a whole. There is little that the commission can suggest, or that the government can require, that would improve the situation in this regard. Rarely is self-interest not the best motivation in such situations.

The third factor mentioned is supervision by EMPR. This will take place as a matter of course, but that does not mean it will be a routine exercise for the inspectors. As in the case of the companies, the government can be confident that if it permits exploratory drilling in the Fraser Valley, ministry staff members will be fully aware that their professional reputations are very much on the line.

A fourth factor suggesting that blowouts are not likely if exploratory drilling took place is the geological information that currently exists about the Fraser Valley. The Georgia Basin, of which the Fraser Valley is a part, has no known overpressure zones. Other geological data suggest no other difficulties to drilling by reason of the geology. Further, the experience of previous drilling in the area, both on the Canadian and U.S. sides of the line in the Fraser Valley, and on the edge of the Georgia Basin near Nanaimo, have all been without record of a problem that might lead to a blowout.

The geology of the region, the high quality of the contractor and crew, and the high level of supervision by the consortium and the ministry do not mean that a blowout is not possible. It is possible, although the possibility is highly remote. The commission believes that the chance of a blowout is no higher than, and probably

[4] The official report of the State of Michigan of the Williamsburg blowout entitled "An analysis of the Amoco State Whitewater "E" 1-22 Well as the Cause of the Natural Gas Eruptions at Williamsburg and Acme, Michigan in April, 1973" was received by the commission as Exhibit T-53. Mr. Nida's testimony begins on page 1348 of the Transcript.

[5] Transcript, page 1403.

much less than, one in five thousand. It is therefore appropriate to consider some of the possible effects of a blowout, were one to occur.

Physical Debris

The commission considered the extent to which the physical debris from a well blowout would endanger public health and safety. In testimony at the technical hearings, it was stated that most of the debris would consist of drilling fluid which was in the well, sand and gravel, part of the drill string, as well as loose tools on the drilling rig. Although the issue of distances is difficult to predict, this debris would most likely be confined to the lease area.

At the technical hearings, Commission Counsel Douglas MacAdams questioned Mr. Bruce Hanwell, Director of Petroleum Engineering at the Ministry of Energy, Mines and Petroleum Resources, on the issue of debris.[6]

> *Mr. MacAdams: Turning now to the term blowout. We've heard this term in other panels, and no doubt we will hear about it this evening. What's a blowout Mr. Hanwell?*
>
> *Mr. Hanwell: Well, I've said it, I believe, and that is an uncontrolled release of gas from the wellbore, because it occurs because the drilling fluid that is or has been in the hole has been displaced by gas entering the wellbore, and if there isn't drilling fluid to counterbalance the pressure inserted by the gas escaping from the productive formation, the gas will find its way to the surface, and be emitted to the atmosphere.*
>
> *Mr. MacAdams: So what gets blown out?*
>
> *Mr. Hanwell: The drilling fluid that's containing the pressure from the zone that's producing the gas.*
>
> *Mr. MacAdams: And is there anything else that gets blown out? One as a layman has this image of heavy metal things being tossed about. Is that a feature of a blowout?*
>
> *Mr. Hanwell: Well, portions, there may be particulate matter, sand or gravel, perhaps a portion of the drill string could also be displaced out of the hole.*

The issue of distances of flying debris is not possible to judge because it is highly dependent on subsurface pressures which vary from site to site. The commission found no evidence that the projection of physical materials from a well blowout has ever injured a member of the public. Such physical debris is primarily an occupational hazard for workers on the site.

Exposure to Methane

The impact that a release of natural gas (sweet, dry gas) would have on human health, via an accidental release, was discussed during the technical hearings. The issue was also examined through the commission's own discussions with medical health officials and through an extensive search of the medical and health literature.

The Canadian Centre for Occupational Health and Safety (CCOHS) describes methane gas, the main component of natural gas, as a simple asphyxiant.[7] The primary concern related to natural gas is the displacement of oxygen in the air. For asphyxiation to occur, oxygen content in the air would have to fall below 18 per cent. Tests on rabbits indicate that these animals can inhale a mixture of 80% methane and 20% oxygen without ill effects.

The CCOHS also reports that methane is not an irritant to the skin or eyes, and is probably non-carcinogenic, not a reproductive hazard, and not mutagenic.

[6] Transcript, pages 767-768.

[7] Canadian Centre for Occupational Health and Safety, *Cheminfo Database*, October, 1990.

The commission spoke to medical health professionals on the topic of public health risks related to natural gas. Dr. John Blatherwick, Chief Health Officer for Greater Vancouver, said that in his 19 years on the job he could not recall a single public health incident related to natural gas and its use. Dr. Raymond Copes, medical specialist in Environmental Health at the Ministry of Health, stated he had never come across a case where natural gas (sweet, dry gas) has been a public health problem. From a toxicological point of view, natural gas appears to be innocuous.

The commission's examination of the medical and health literature consisted of a computerized search of four databases: Medline (1983-1990), Toxline (1981-1990) the National Technical Information Service (1964-1990), as well as the database NIOSHTIC, produced by the National Institute for Occupational Safety and Health. The commission was unable to find any evidence that natural gas has represented a toxic hazard to public health and safety.

The commission also examined whether methane found in drinking water will have adverse human health effects.

The most comprehensive studies found by the commission on this issue were conducted by the Midwest Research Institute (MRI), a scientific research consultant based in Kansas City, under contract with the American Gas Association. In MRI's first report, entitled "The Impacts of Natural Gas on Drinking Water and Human Health" (1978), the consultant concluded that methane or natural gas dissolved in drinking water posed no toxic hazard to humans. Moreover, the consultant determined that the solubility of methane in water was so low that a person would have to drink approximately forty 7-ounce glasses of water saturated with methane in a twenty-four hour period to ingest the amount of methane normally exhaled or otherwise released from some humans.

In MRI's second report, entitled "The Effects of Natural Gas on Drinking Water Sources" (1980), the consultant examined the interactions of natural gas with different constituents in water, to determine possible endangerment of drinking water resources. These constituents were sulfates, chlorine and odorants.

The consultant concluded that "natural gas will not react with any constituent in drinking water in a way that could adversely affect the health of persons." More specifically, the consultant concluded:[8]

1. *That sulfate to sulfide reduction, based upon analysis of existing information, will not be encountered in conventional practices of underground storage of natural gas in this country.*
2. *That chlorination of water containing methane and other low molecular weight aliphatic hydrocarbons will not generate trihalomethane.*
3. *That the amount of odorant which can be dissolved in water associated with underground storage of natural gas is miniscule and cannot adversely affect the health of persons.*

The commission contacted MRI during the summer of 1990 to determine if the Institute was aware of any further studies in this area. The spokesman for the Institute said he knew of no significant new material, and did not expect to come across any, as the many scientific papers of past years overwhelmingly supported their conclusions. The results of its research in this area appear, therefore, to be current, and to represent modern scientific thinking, a fact confirmed by British Columbia health officials contacted during this study.

[8] Midwest Research Institute, 1980, page 8, in the Commission Record.

Explosion or Asphyxiation

The commission examined the issue of an accumulation of natural gas, and the potential for such an event to occur. At concentrations of between 5% and 15.4%, methane is explosive in confined spaces. However, since methane is lighter than air it will quickly dissipate when released, provided it is not confined. The CCOHS states that the safest disposal of natural gas is for it to dissipate into the atmosphere, or for it to be burned.

According to a U.S. Department of Energy's 1989 study, it appears highly unlikely that a methane explosion could occur in an unconfined space without a high explosive detonator. Such explosions have been observed experimentally only when triggered by one kilogram of high explosive.[9]

Based upon an examination of the pertinent medical and health literature, the commission found no evidence that a significant ground level accumulation of sweet natural gas following a well blowout has ever occurred, or that such a release has resulted in explosion.

Mr. Bob Spring, Manager of the Fraser Valley Gas Project, described such a situation as follows:[10]

> *On the subject of a blowout, and the concern about sweet gas or methane natural gas, there are many cases on the record where during a natural gas blowout that contained only methane the blowout was not ignited, and the blowout was subsequently brought under control.*
>
> *Most blowouts of any kind of natural gas ignite due to sparks from equipment, or electrical equipment on the rig. I know of no incident where raw methane escaping from a blowout has travelled somewhere off-site and been subsequently reignited. So, we're not aware of a situation where it's a worry that methane travels and does not disperse and accumulates somewhere and presents a danger.*
>
> *In conjunction with that, however, for the emergency response plan, there will be mobile vans moving through the area monitoring the air quality specifically looking for concentrations of natural gas. And, of course, the final point to make is that in the history of western Canadian oil and gas activity, there is no recorded incident of a resident being killed. All the injuries, and any deaths associated with blowouts have occurred on the lease. That's just to clarify the dangers of a sweet gas blowout.*

Mr. Bruce Hanwell, Director of Petroleum Geology, Ministry of Energy, Mines and Petroleum Resources, had a slightly different view. He stated that the possibility did exist for natural gas to accumulate, even though this possibility was very remote:[11]

> *I guess the only comment I have to make is that I have heard a number of people during this inquiry state that sweet natural gas would be dispersed upwards, and that there's really no risk. I can't buy that 100 per cent. I don't think there's any guarantee; that even though it may be rare, I believe there still could be a situation whereby you could have an accumulation say from a blowout that may cause an explosive mixture, and perhaps cause an explosion on the surface.*

Dr. D.M. Leahey of Western Research, a consulting firm specializing in the assessment of gas dispersion, prepared a paper[12] calculating ground level concentrations of natural gas resulting

[9] J.B. Ranjan, C.L. Saricks, M.K. Singh and W.J. Walsh, "Environmental, Health and Safety Concerns Associated with Nonpetroleum Fuel Use in U.S. Transportation", June 1989, sponsored by U.S. Department of Energy, p. 38.

[10] Transcript, pages 795-796.

[11] Transcript, page 1444.

[12] Dr. D. M. Leahey, "Estimated Ground Level Methane Concentrations Resulting from a Natural Gas Well Blowout in the Fraser River Valley", Western Research, September, 1990, in the Commission Record.

exist in this area and is not a threat. By contrast, in Alberta, where 25 thousand productive gas wells were drilled in the two decades 1960 to 1980, most of the natural gas was contaminated with hydrogen sulphide.[17]

Dr. Bustin concludes that the possibility of sour gas being found in the Fraser Valley is remote:[18]

> *Based on the evidence at hand, there is a very low probability of significant H_2S being associated with any pooled hydrocarbons in the Fraser Lowland.*

The presence of hydrogen sulphide in the Fraser Valley cannot be completely discounted. Only drilling can provide the information about the subsurface geology of the Fraser Valley and determine the matter definitively. However, given past drilling activity and recent geochemical analysis in the Fraser Valley, the likelihood of encountering sour gas is very remote.

For sour gas to pose a hazard to local residents, not only would it have to exist underground, but it would have to escape from the wellbore. A leak or blowout, in other words, would have to occur. The blowout preventer would have to fail, resulting in an uncontrolled release of gas. In addition, ignition of the escaping gas would have to be unsuccessful.[19] For all these conditions to exist in the appropriate sequence is unlikely in the extreme.

Physical Ailments Due to Noise

The issue of noise from a drilling operation was raised by the public. Specifically, the concern was expressed that drilling noise would cause a loss of sleep and take a significant physical toll on nearby residents.

The commission examined the noise issue and found that the proposed drilling operations will produce noise levels that are within the acceptable limits under local noise bylaws. The Fraser Valley Gas Project consortium, moreover, has indicated that it will limit noise to the extent possible, and will use a variety of noise suppression equipment in its operations.

As discussed in the section on noise in Chapter 8 of this report, the consortium indicated that the noise level from drilling is 60 dba at 100 metres, and this may be further reduced to 50 dba at 100 metres with additional equipment.

Given that the closest residence at any of the proposed drilling sites is over 125 metres away, and that the above noise levels are within local bylaws, it is not expected that drilling activity over a period of six weeks will cause excessive physical strain on nearby residents.

Psychological Impacts

During the inquiry, a public concern was expressed that the presence of oil and gas facilities and the existence of a 24-hour emergency evacuation plan could lead to psychological ill-effects among some Fraser Valley residents. The position was advanced that psychological counselling services should be provided to Fraser Valley residents as part of any oil and gas program.

The commission inquired into the provision of psychological counselling services at other oil and gas projects, and found no evidence that such special programs have existed or that they have been considered necessary. The commission, however, is well aware that change in a community, and more

[17] D.W. Layton *et al.*, *"Accidental Releases,"* p. 23.

[18] Exhibit T-34, page 18.

[19] The testimony of Mr. Morin and Mr. Nichol of the Energy Resources Conservation Board of Alberta was most interesting on the subject of burning sour gas. The Lodgepole incident has apparently persuaded the industry of the importance of burning. See Transcript, page 908 ff.

specifically, the introduction of a new industrial activity in an area after a long and emotional battle to prevent it, can affect local residents in many different ways.

Where concerns or problems exist relating to the mental health of local residents, steps obviously should be taken which minimize or counteract these impacts. The commission foresees two situations where psychological difficulties could arise.

The first situation involves those people who have a general phobia or fear of oil and gas activity, but who are not suffering from a psychologically debilitating condition. In such cases, individuals should attempt counselling to examine objectively the risks surrounding oil and gas activity, and determine whether their fears are actually warranted.

The second situation where adverse psychological impacts could occur would be the result of an emergency or accident due to petroleum industry activity. In the event of an accident involving the public, psychological counselling treatment services would be provided. The Mental Health Services Division has indicated to the commission that as part of the Provincial Emergency Program, Mental Health Centres in the province are prepared to respond to such crisis situations, just as they would in the case of a train or aircraft accident which led to adverse psychological impacts.

Currently there are 54 Mental Health Centres and sub-offices throughout British Columbia. In the event of an incident, services would increase in a given area, depending on the severity of the emergency. Generally, Mental Health Services are called upon several days after an emergency, once the physical well-being of victims has been addressed. Thereafter, Mental Health staff will provide care to those who were traumatized by the emergency situation.

In short, the provincial machinery appears to be available to handle this problem. The commission makes no recommendations in this regard.

Emergency Response Plan

By reason of the population density in the Fraser Valley, the Ministry of Energy, Mines and Petroleum Resources designated the proposed exploratory wells in the Fraser Valley as special wells. Special well designation in the Peace River and southeastern British Columbia is generally for wells which may result in a sour gas find. The chances of such a find in the Fraser Valley, for reasons that are outlined above, are remote, but cannot be ruled out entirely until further drilling is done, assuming that the government allows such drilling to take place. Before drilling of a special well, an emergency response plan is required, the planning zone being a one kilometre radius from the well. It is thus a requirement in the Fraser Valley.

An emergency response plan is outlined in Exhibit T-32, provided by the consortium. Mr. Ed Nordquist, Drilling Superintendant for Conoco Canada in Calgary, outlined the plan at the technical hearings. It was further explained by Mr. Graham McCredie of United Resource Safety, who testified at the hearings as part of the Conoco panel.[20] As described, the plan includes definitions of emergencies, the action that should be taken in response to an emergency, resident information, public and media communications plans, contact information for public agencies, and the arrangements for the provision of support services.

Mr. Nordquist stated:

> *A Level I alert would be an incident such as lost circulation, stuck pipe, the detection of an influx of formation fluids into the wellbore, or any other deviation from normal drilling*

[20] Transcript, page 755 ff.

operations. Monitors to detect these problems will be on location and operational from the start of the well. A Level I alert is an incident that is confined to the lease with no immediate risk to the public. Even though the alert is confined to the lease, a portion of the response plan is put into effect. All well site people who have specific duties, including around the clock safety people, will be placed on alert when one of these conditions arise. The response team that phones the residents to warn them of a problem are placed on alert, and the EMPR, RCMP and the PEP, which is the Provincial Emergency Program representative, are placed on alert.[21]

Should the condition progress to a Level II alert, a condition which allows uncontrolled gas to be released, or the potential for a fire exist, the evacuation plan would be put into effect. The affected residents would be called and told to evacuate, and the necessary government authorities notified. Residents that require assistance to evacuate will be helped.[22]

A Level III alert is when uncontrolled gas must be ignited to protect the area from damage caused by the uncontrolled flow. All affected residents in the planning zone must be evacuated, and the area secured so that no one enters the planning zone. The RCMP would be called in to provide resident security.[23]

We don't feel the ERP will ever need to be implemented but it is a step that must be taken as part of the plan to drill in the Fraser Delta. Even if a drilling emergency were to occur, it is unlikely that extensive evacuation would have to be implemented since no sour gas is expected to be encountered.[24]

The commission has examined the proposed emergency response plan, and finds it to be entirely adequate under the circumstances. It notes, however, that at the public meetings the plan appeared to be generally misunderstood, and often was taken as an indication of a belief by EMPR that exploratory drilling is a very high risk affair.

The public's misunderstanding in this regard is quite logical. Many other, far more hazardous industrial activities take place in the Lower Mainland area without such plans being in place. Rail transportation of hazardous products creates risks in the Fraser Valley similar to those that the Mississauga derailment highlighted a few years ago. The transportation of chlorine, to choose another example, takes place in the region on a regular basis by water and by rail. The risks of possible chlorine gas affecting many thousands of people exist as a result of this transportation, yet few are made aware of it by way of a publicized emergency response plan or evacuation plan. The commission has no views on whether such a chlorine accident response plan is necessary, desirable, or useless and irrelevant. The matter is mentioned here only to indicate that the existence of an emergency response plan for exploratory gas drilling in the Fraser Valley, and the lack of response plans for other hazards, logically suggests to some members of the public that the risks may loom larger in the minds of EMPR officials than they have been led to believe.

The commission is of the view that if the government allows drilling to proceed, the Ministry of Energy Mines and Petroleum Resources should, in conjunction with the consortium, embark upon a public information campaign to point out

[21] Transcript, pages 784-785.
[22] Transcript, page 787.
[23] Transcript, page 790.
[24] Transcript, page 804.

precisely what the technical evidence suggests the risks of drilling to rig workers and nearby residents to be, and to point out that the emergency response plan is not related to any comparative risk from other sources, but is related only to the common sense requirement of the legislation that some, relatively minor, preparation be made for a highly unlikely event.

A second public misunderstanding about the emergency response plan that came up frequently during the public hearings can be laid at the door of the consortium, not EMPR. This was an incautious statement by a company representative before this commission was established that the evacuation of domestic and farm animals would be included in any emergency response plan. The commission recommends that this proposal be rejected.

RECOMMENDATION 15

Emergency Response Plan

That an emergency response plan for a drilling rig accident in the Fraser Valley initially should be for the very limited purpose of clearing an area near the rig of people. Subsidiary objectives, particularly subsidiary objectives that may require large numbers of people to be in the area for a long period of time, will make the plan less effective for this primary purpose, and should not be included.

This does not mean that in the event of an emergency all domestic and farm animals will undoubtedly die, as some of those who spoke at public meetings seem to believe. If an evacuation takes place, the length of time people will be away from their houses is likely to be very short — in fact only the time required to be sure that the escaping gas is not sour and that the escaping sweet gas does not pose a fire hazard to nearby buildings. Under those conditions animals will quickly again be under the care and control of their owners.

In the highly unlikely event that sour gas did occur, and if for some reason it was not possible to ignite it (and thus remove the H_2S from the air of the area) the rounding-up and transportation of farm and domestic animals during the evacuation would be dangerous. Under those circumstances, it must be accepted that some of them might be killed or otherwise affected by the gas. However an attempt to rescue them during the emergency evacuation of humans in the neighborhood would run unnecessary and unjustifiable risks.

RECOMMENDATION 16

Exclusion of Animals in Emergency Response Plan

That the evacuation of domestic and farm animals not be included as part of the emergency response plan of the Fraser Valley Gas Project consortium.

Positive Health Impacts

The health results of the industry's activity in the Fraser Valley are not all negative. It is necessary also to note the high positive impact on human health of increased natural gas use in the Lower Mainland that might result from finding gas or a storage facility in the Fraser Valley. If such finds do lead to increased gas use by reason of lower prices and greater security of supply, and air quality is thereby improved, the effect can be expected to be positive.

The commission has not attempted to delve in any depth into the medical literature to determine the levels of contaminants or particles in the air that result in distress to asthma or emphysema victims. Nor has it attempted to learn how

various kinds of pollens combine with various emission contaminants to cause unusual levels of human discomfort. It notes the work being done by the Department of Health Care and Epidemiology of the Faculty of Medicine of the University of British Columbia in this area. Those interested in further material may wish to examine the literature,[25] and discuss the situation with the researchers involved. It is sufficient for the purposes of this inquiry to indicate that a reduction in photochemical smog and better air quality through the greater use of natural gas can be expected to reduce respiratory distress, particularly among children and the elderly, and this can reasonably be expected to reduce present levels of mortality and morbidity in the Lower Mainland from this cause.

Physical Security of Petroleum Exploration Facilities

A further safety issue relates to the physical security of petroleum exploration facilities. If the government permits exploratory drilling, the petroleum exploration installations in the Fraser Valley would be manned around the clock. Nevertheless, it would be advisable to take further measures to ensure that these installations are nonetheless physically secure.

Acts of vandalism have been committed against resource industries in this province and there is no reason to believe that the petroleum industry will remain immune from this activity. Even installations considered secure, such as hydro facilities, have suffered significant vandalism damage, incurring danger, expense and inconvenience to the owner and the general public. Further, petroleum industry intallations in the Fraser Valley may attract children, who might suffer injury as a result.

Security measures potentially include installation of fences, gates, security lighting and alarm systems for areas not frequented by operational employees. Deployment of security personnel may also be indicated. "Security surveys" can be conducted by crime prevention professionals trained in industrial security who are able to make cost-effective recommendations on the reduction of crime-related losses.

RECOMMENDATION 17

Anti-Crime Security Standards

That anti-crime security standards be set for petroleum and natural gas installations.

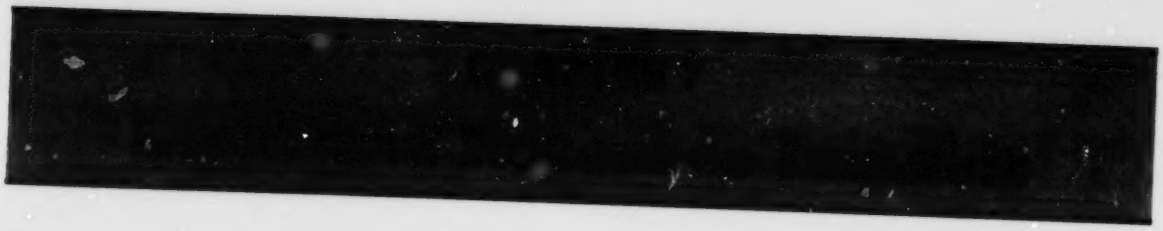
These might be included in a new Division of the *Drilling and Production Regulation* or in the Ministry's Procedural Handbook.

RECOMMENDATION 18

Security Survey Requirement

That s. 105 of the* Petroleum and Natural Gas Act *be amended to require the preparation and submission of a security survey with rig licence applications. The licence would be issued on the condition that the appropriate security recommendations in the survey be met.

[25] See for example, "Asthma Attack Periodicity: A Study of Hospital Emergency Visits in Vancouver", a paper by D.V. Bates, M. Baker-Anderson, and R. Sizto, published in *Environmental Research*, 1990, 51, pages 51-70.



Agriculture

The impact of the exploratory program, and the possible impact of underground natural gas storage on agriculture were frequent subjects of concern at public meetings. Most of those who expressed such concerns were not working farmers, but residents in the estate/residential or rural/residential areas of the valley.

The commission was reminded that there are almost $100 million worth of horses in the Langley area, and their owners spoke up vigorously on behalf of their animals on a number of occasions. Some breeders of other livestock also spoke or wrote letters. These included persons raising pheasants, quail and other more exotic birds, dog breeders, and other animal breeding specialists. Those practising intensive agriculture on small parcels of land also expressed concerns, as did those accurately described by the commission's consultant in the area, Mr. Gary Runka of Runka LandSense Ltd. as practitioners of "non soil-bound agriculture".[1] In this agricultural category are those using buildings rather than fields, to raise poultry, mushrooms or similar indoor crops. Again, Mr. Runka's graphic description of this type of agriculture as "building-oriented biological manufacturing enterprises" appears entirely apt.[2]

In contrast to opponents of drilling, the Delta Farmers' Institute (representing the majority of the working farmers of the Delta area) contacted the commission to inform it of the views of its members, which were to the effect that drilling should be permitted. Further, the Institute requested that the Commissioner attend a meeting of its membership, to permit the Commissioner to hear their views. A lengthy and most interesting meeting took place, which confirmed that many of the members of the Institute indeed support drilling. At the same time, the Commissioner was informed of the difficulty that many farmers face in keeping their farms going in the face of crawling, or more correctly galloping, urbanization in which they generally include the estate/residential and rural/residential developments. There are clearly many threats to Fraser Valley farmland and agriculture.

[1] Transcript, page 124.
[2] Ibid.

Land Alienation

There are a number of aspects to the issue. First, it is clear that exploratory drilling will require some alteration of land use in the short run when the drilling is in progress. The consortium has indicated that at each of the Murray Creek and Campbell River sites, for example, some 1.7 hectares of land will be required, while slightly less (1.6 ha) will be required at Boundary Bay. In total this comes to 5 hectares, which is much the size of a single estate/residential property.

Further, there will be some alterations to the land cover. At Campbell Creek it will be necessary to remove 0.3 ha of timber, and at Murray Creek tree removal will be required on about half that area. Thus the loss of trees will total about 0.5 ha.

The land in question is in the Agricultural Land Reserve, and part of it is in agricultural production. Thus exploratory drilling will result in temporary impact on agricultural production.

In the Event of No Discoveries

Following the drilling, assuming nothing is found, the land will be restored to its

previous condition, as far as that is possible, unless landowners wish the road facilities to remain. From the records of previous drill sites in areas of prime agricultural land in the Fraser Valley, in northern British Columbia and in Alberta, and in particular in Ontario and Europe, this restoration can be expected to be entirely successful, with one possible exception — that is, possible compacting of soil from the heavy equipment used. The long term effect of compacting soil after an industrial use of agricultural land is not clear, and the commission has not found direction from the literature. No ill-effects from compacting were visible at the Nanaimo sites, and no evidence was presented that compacting of soil has been a problem at any of the 150 other petroleum wells drilled in the Fraser Valley on both the American and Canadian sides of the line. Further, no evidence was presented to the commission that the heavy equipment used in water well drilling of the ten to twenty thousand water wells in the area has resulted in long term soil compacting. Given the small amount of land involved, and the uncertainty of any long term detrimental effect to the restored agricultural land, the commission is of the view that this can be discounted as a major matter of concern.

In the Event of a Commercial Discovery or Underground Storage

If the drilling results in a commercial find, then about a quarter of the property in question will remain covered with wellhead equipment, a gravel pad, and access roads. Also, there will likely be further drilling on the gas reservoir, which will expand the area taken out of agricultural production. In addition, further exploratory activity will likely take place. Without the results of exploratory drilling, there is little way that the amount of land that might ultimately be taken out of production by a commercial find can be calculated; however, experience elsewhere suggests it would be unlikely to exceed six hectares.

This overall acreage is not the only factor to consider. For instance, farmers cannot work fields that are broken up with too large a number of hydro pylons or transmission stations, road systems or petroleum wellheads or other such facilities. Although the overall acreage may not be great, the location of such facilities may result in considerable difficulty and extra expense to the farmer as he or she works around the obstruction.

Deviated (directional) drilling, illustrated in Plate 14, indicates how losses of agricultural land can be minimized. It should be recognized that some multiple use is also possible. Ontario and France provided the commission with striking examples of small isolated (5 metre by 8 metre) wellheads surrounded by growing crops. When it is necessary to visit the wellhead with equipment, the petroleum company waits until the crop has been harvested, and then moves the equipment over the bare ground. In the rare event of a need to get to the wellhead when the crop is still standing, a path to the wellhead is made through the crop, which is sacrificed, and for which the farmer receives compensation.

Thus the amount of land actually owned or leased by the petroleum company in the farming area is a deceptive measure of the amount of land taken out of agricultural production. Farmers are encouraged to grow crops up to the edge of the facilities, even though the land may be owned, or leased, by the company.[3] The company, if it is obliged to move across the land in question, pays compensation even though it is moving over land to which it has the surface rights. The farmers, not unnaturally, find the system attractive. They receive rent for the land, or else they receive the purchase price (which is almost invariably above the price the land would fetch as agricultural land). They are still able to farm it,

[3] See in particular the testimony of Mr. Yannick Guerrini and Mr. Ivan Cuthill, Transcript, pages 1255 ff.

without payment to anyone. If there is any crop loss, even though the land is owned or leased by the company, they receive compensation.

Another factor is that the possibility of augmenting agricultural income with petroleum revenues is very attractive to many Fraser Valley farmers. As the Commissioner heard a number of times when discussing the matter with working farmers, it is not easy to make a living farming in areas which are rapidly acquiring an estate/residential, or rural/residential character. Many reasons were given. Perhaps it can be summed up by the farmer who colourfully described how difficult it now is to move farm machinery between his properties on local roads, now that those roads have so many Accords, Acuras and Audis rushing their owners to offices in Richmond and Vancouver. There is a constant temptation on farmers to give up the battle, to sell out and move. These farmers are of the view that extra income from the petroleum industry would be a great help, not only to them financially in the personal sense, but also as a means of making farm operations overall more viable, and thus protecting farmland.

One other factor should also be mentioned, namely the general desire of the petroleum industry to have buffer zones around its facilities. Forested land, or agricultural land, is very attractive from that point of view. For example, in the event that a compressor station is established for an underground natural gas storage facility, the consortium would naturally be interested in using distance from those who might be affected by the noise as a means of reducing their noise suppression costs. This is straightforward. The compressor station could be established in a suburban or urban area (as in California and many other jurisdicitions). If so, noise supression would require the expenditure of fairly large sums of money. Land in populated areas is also likely to be more expensive. By having the compressor station situated some distance from subdivisions or urban areas, there is likely to be less cost for land acquisition, less cost for site design and development (placing the facility seven metres below the ground surface, for example, or erecting five metre earth berms) and less cost for soundproofing walls, mufflers, and other sound suppressing equipment. Thus it can be seen that the petroleum industry, as suspected by Fraser Valley naturalists interested in habitat protection (this is discussed further in this chapter under the heading of Wildlife), will indeed be interested in maintaining agricultural land in the Fraser Valley, and indeed, will be interested in opposing subdivisions near or over its facilities. Conversely, this fact also provides an explanation as to why some developers and real estate promoters are hostile to the industry gaining a foothold in the Fraser Valley.

Conclusion

The commission regards the impact of the petroleum industry on agricultural land and the agricultural industry as a very important issue in determining whether the exploratory drilling should be allowed to proceed. Further, it notes that the pressures on agricultural land in the Fraser Valley are many, and overwhelmingly in the direction of reducing or eliminating such use for the land.

In its view, if no discoveries occur, the petroleum exploration proposed by the Fraser Valley Gas Project consortium will have a very minor impact on about five hectares of land, an impact that will not be detectable two years after the program is completed. If a find of commercial size occurs, less than 6 hectares of land, which may or may not all be agricultural land, will be required. Against this, the wider impact of the industry's activities will be to increase agricultural incomes and to provide incentives to protect agricultural land from development. The amount of

land which may be affected in this way may total many square kilometres.

With respect to horses and other livestock, the noise level of petroleum industry facilities may be a problem at certain times of the year. Pregnant mink are known to be very sensitive to loud noise, and are affected by aircraft overhead. However the commission received no evidence that horses are similarly sensitive, and require special protection. There was no evidence presented that any other industry in the Fraser Valley has been required to meet reduced noise levels by reason of the proximity of horses or other animals, or any evidence that any municipality has established noise bylaws with horses or other animals in mind. Given the ability of the industry to reduce noise levels, by location, design, and noise suppression, the commission does not foresee a significant problem in this regard. It is of the view that horses and other animals (with the possible exception of mink) will be unaffected one way or another.

Overall, the commission has concluded that the impact of the proposal of the Fraser Valley Gas Project consortium on agriculture and the protection of farm land can be expected to be positive.

Fish and Wildlife

The impact of petroleum exploration on fish and wildlife in the Fraser Valley was considered by the commission. Three government organizations were contacted in this regard: the Lower Mainland Regional Headquarters of the British Columbia Ministry of Environment; the Regional Office of the Canadian Wildlife Service; and the Pacific Regional Office of the Federal Department of Fisheries and Oceans. The British Columbia Wildlife Federation and some of the component clubs of that organization in the Fraser Valley were also contacted. Other environmental and fish and wildlife organizations expressed their views by letters and telephone, while public meetings gave individuals interested an opportunity to voice opinions.

Fish

In terms of the potential impacts on fish, the Department of Fisheries and Oceans has reviewed the pertinent literature and indicated that natural gas does not pose a major toxic threat to fish.[4] Natural gas is composed of methane, which is only slightly soluble in water. In the case of water saturated with methane, methane levels would not exceed thirty parts per million at water temperatures of between five and ten degrees Celsius. When young rainbow trout were exposed to oxygenated well water with the maximum saturation level of natural gas, they suffered no mortalities during the eight hour test period. Minnows were not affected by a saturated methane solution during a two hour test period.

While the Department of Fisheries and Oceans is not concerned about the toxicity of natural gas on the fisheries resources, that department is concerned about the operational aspects of gas exploration. These aspects include road and access construction, drilling mud use and disposal, mud and fuel spill contingencies, site abandonment and reclamation, and agency notification. The Department of Fisheries and Oceans informed the commission that these issues are not characteristically decision-critical, and are addressed as "house-keeping" matters by the responsible federal agencies. The commission is of the view that the exploratory drilling program in the Fraser Valley as outlined by the Fraser Valley Gas Project consortium, and the requirements of the EMPR, effectively address these concerns.

[4] Letter to the Commissioner from John Payne, Acting Chief, Habitat Management Division, Department of Fisheries and Oceans, August 27, 1990.

Endangered Fish: The Salish Sucker

At a public meeting of the commission, a Fraser Valley resident raised the issue of the impact of petroleum exploration on an endangered species of fish in the area, the Salish Sucker. The commission contacted Dr. Don McPhail, a professor of zoology at the University of British Columbia, and a specialist on this fish, who kindly assisted the commission in this regard. Ms. Ann Hillyer, of the West Coast Environmental Law Association, also was most helpful.

Dr. McPhail indicated that the Salish Sucker is clearly endangered in British Columbia.[5] Its distribution is restricted to the headwaters of the Campbell and the Salmon rivers and Bertrand, Pepin and Salwein creeks in the lower Fraser River Valley. Its numbers have declined in all areas, and in Campbell River the fish may already be non-existent. Dr. McPhail explained that the main limiting factor on the Salish Sucker appears to be lack of suitable habitat, due to the increasing urbanization of the Fraser Valley. He wrote:[6]

> *As the area around Langley and Aldergrove becomes increasingly urban, the streams that support the species are changing. The riparian vegetation is shifting from alder bush to pasture and domestic lots. Summer water temperatures are increasing and summer flow decreasing. The streams are prone to flash flooding, and thus are increasingly subject to ditching and other control measures . . .*

Dr. McPhail stated that the future survival prospect of the Salish Sucker is poor, but that oil and gas exploration in the Fraser Valley, properly carried out, would likely have a negligible impact on the fish. He stated, however, that the operational aspects of such activity should not be forgotten, as a direct spill of oil or other contaminant into a creek would certainly have an adverse effect on this fish.

The commission believes that oil and natural gas exploration in the Fraser Valley, properly carried out, will not impact the Salish Sucker. It notes with alarm that this endangered species appears doomed to extinction unless energetic measures to protect its habitat from other threats are undertaken. It notes further that British Columbia, unlike the province of Ontario, lacks endangered species legislation. The *Wildlife Act* is not, with respect to protecting endangered species, an adequate legal tool.[7]

The likely extinction of the Salish Sucker in British Columbia should be a matter of serious concern for this province, yet very little attention appears to have been devoted to the issue, other than through the efforts of Dr. McPhail and a handful of other dedicated naturalists. Protection of endangered species is not within the terms of reference of this commission, other than as an adjunct to its study of the possible impact of the petroleum industry. However the importance of the issue has arisen in the study of the petroleum industry that this commission has undertaken, and it is for that reason that recommendations for its protection are found below. When faced with the likelihood of the extinction of a species, a liberal and constructive interpretation of the terms of reference assigned by His Honour the Lieutenant Governor appears in order.

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[5] The commission has since learned that the fish is on the endangered list of the Federal/Provincial Committee on the Status of Endangered Wildlife in Canada.

[6] J. D. McPhail, "Status of the Salish Sucker, Catostomus Sp., in Canada". *Canadian Field-Naturalist*, 1987, 10(2), pages 231-236.

[7] An important article by Mr. Calvin Sanborn of the West Coast Environmental Law Association outlining the need for such legislation and what it might contain is found in the recently published report by the Law Society of British Columbia entitled *Law Reform for Sustainable Development in British Columbia*.

RECOMMENDATION 19

Endangered Species Habitat Protection

That a protection plan for river habitat of the Salish Sucker be developed by the Habitat Management Division of the Fisheries Branch of Environment B.C.

RECOMMENDATION 20

Endangered Species Legislation

That endangered species protection legislation, modelled on the Ontario* Endangered Species Act, *be introduced in British Columbia.

Wildlife

The impact of petroleum exploration on wildlife in the Fraser Valley was also considered by the commission. The Canadian Centre for Occupational Health and Safety provides animal toxicity data for methane. Information from the Centre indicates that methane is non-toxic for both humans and animals, and that the primary adverse health impact for both is asphyxiation in situations where methane concentrations reduce oxygen to below the levels necessary for survival. Studies indicate that the concentration of methane in air must be high for asphyxiation to occur. In mice, an 87% methane concentration causes asphyxiation. Rabbits were able to inhale a mixture of 80% methane and 20% oxygen without displaying any ill-effects.

Given the fact that the maximum concentration of methane in air due to a 100,000 cubic metre a day blowout at 30 metres downwind is expected to be about 1.2%, and further that the lower flammability limit of natural gas is a 5% concentration, wildlife is not threatened by a release of natural gas into the environment, either from asphyxiation or fire. As mentioned previously in Chapter 6, a methane explosion in an unconfined space is probably not possible without a high explosive detonator. A methane explosion in the atmosphere appears highly remote and of no risk to wildlife.

Wildlife biologists with the B.C. Ministry of Environment and the Canadian Wildlife Service did not foresee any significant impact from exploratory natural gas drilling on wildlife in the Fraser Valley.

The main issue that was raised was the loss of habitat for different birds and small mammals. Although the parcels of land required for petroleum exploration are small, and are certainly dwarfed by the subdivisions, industrial parks and shopping centres of the rapid urbanization in the Fraser Valley area, gas drilling activity might have some impact on the availability of wildlife habitat.

Two specific issues were raised regarding habitat in the Fraser Valley. The first is that the Fraser Valley is a very important and unique wintering area for birds, particularly waterfowl, and consequently efforts should be made to preserve bird habitats. The commission inquired into the best period during the year for drilling to take place, considering the fact that the Fraser Valley is such an important wintering location. The biologists indicated that drilling in the spring and summer months would have far less impact on the bird population than drilling in the winter months.

The second issue concerned the loss of oldfield habitat, which is a threat to the common barn-owl, which despite its name, is not particularly common on this part of the Pacific Coast. The Fraser Valley is the center of the British Columbia distribution for this owl, which preys on small mammals such as voles.[8] It is important that such habitat be respected. If drilling

[8] R. Wayne Campbell et al., *The Birds of British Columbia*, Volume 2. Royal British Columbia Museum, 1990, pages 352-355.

occurs on this habitat, impacts such as noise should be contained and the amount of land used minimized. If gas reservoirs or gas storage reservoirs are not discovered, the habitat should be returned to its natural state.

The commission found that the impacts of the proposed drilling program on wildlife resources have been well researched by the proponent consortium. The consortium retained wildlife consultant, Mr. Donald Blood, to assess the potential wildlife impact at the three proposed drilling sites. Conclusions on wildlife impacts are set out in the environmental report prepared for the proponents by Regional Consulting Ltd.

In terms of habitat loss or alteration at the Boundary Bay site, the consultant stated:[9]

> *The 1.6 ha of land to be used for access and temporary work-space has, at the site itself, no special value for wildlife. No significant impact on habitat is anticipated.*

The consultant also concluded that disturbance due to noise and activity at Boundary Bay would not be significant:[10]

> *The short time period and relatively low noise levels associated with this project, in the context of existing disturbances which foreshore birds have adapted, suggests that the drilling program could be carried out at any time of the year without significant, harmful disturbance of Boundary Bay foreshore birds. However, the highly seasonal nature of bird use in this area also affords an opportunity for drilling to occur at times when almost no birds are present (May through August).*

In terms of impacts at the Campbell River site, the consultant concluded:[11]

> *No critical wildlife activities or unique wildlife habitats are known to occur in proximity to this site. The very small area of habitat to be affected is not of any regional significance. The short duration and relatively low noise levels associated with drilling here should not adversely affect those species of wildlife which are adapted to a semi-settled landscape.*
>
> *Measures taken to protect water quality and fish resources (drilling fluid control, erosion control, etc.) will also protect aquatic and riparian wildlife species.*

The consultant also found wildlife impacts to be minimal at Murray Creek:[12]

> *For reasons discussed with respect to the previous site, no significant wildlife impacts are expected to occur at this site.*

The commission's consultations with citizens, fish and game, and naturalist groups support these conclusions. Indeed, some Fraser Valley naturalists appear to believe that if the petroleum industry is permitted to drill and if the results are encouraging, the industry will become an important ally in the inevitable wildlife habitat protection battles of the future. They understand that the industry elsewhere has preferred to operate in areas of lower human population densities, and they expect it to impede human settlement near its facilities in the Fraser Valley, thus giving habitat space for birds, fish and other wildlife.

Animal Habitat

The commission suspects that this positive attitude of some Fraser Valley naturalists to the consortium may have been engendered by the role Conoco has played

[9] Regional Consulting, "Natural Gas Drilling Program in the Fraser Valley — Environmental Report," 1990, p. 24, in the Commission Record.
[10] Ibid, p. 25.
[11] Ibid, p. 26.
[12] Ibid, p. 27.

in bringing the Whooping Crane back from the edge of extinction, through protection of its wintering grounds at Aransas, Texas, which is also a petroleum production field. Conoco has pamphlets in its information package and at its public offices which outline its activities in this regard, for which it has received environmental awards, and for which it is justly proud. With respect to B.C. Gas, it is possible that its current advertising campaign based on frogs and other swamp animals approving of humans switching to the less polluting fuel of natural gas has had an impact on those in our society who have special interest in nature and animal habitat protection.

Whatever the reason for the views of these naturalists, the commission is of the view that they are probably right. If production or storage eventually takes place as a result of positive exploratory drilling, the consortium will actually occupy (i.e., cover with buildings, gravel pads, roads or parking lots or otherwise remove the land from its natural state) very little land, probably six hectares. The commission has further concluded that the buffer zones to such facilities which the consortium will wish to establish whether leased, covenanted, or purchased, will be far more extensive, probably totalling five hundred hectares. In addition the industry's impact on agriculture may be to reduce urbanization pressures over many square kilometres. The conclusion of the commission in this regard is that from the point of view of habitat protection for birds, fish and mammals, the presence of the petroleum industry in the Fraser Valley is likely to be a positive, not a negative, factor.

Archaeological Resources

The commission inquired into the impact of petroleum exploration on archaeological resources in the Fraser Valley. Archaeological resources, whether on public or private land, are protected under *The Heritage Conservation Act (1979)*. Under the Act, archaeological resources may not be destroyed, excavated or altered without permission from the Minister or his designate.

The Archaeology Branch at the Ministry of Municipal Affairs, Recreation and Culture is responsible for the management of archaeological resources in the province. In the Archaeological Resource Management Handbook, the Branch describes the importance of archaeological resources, and outlines provincial government policy where land uses conflict:[13]

> *Archaeological sites are valuable provincial resources, as are mineral deposits, arable land, forests, and fish and wildlife. In addition to their scientific and public value, archaeological sites may also have economic value to B.C.'s recreation and tourism industries. The protection of significant archaeological sites so that their intrinsic values may be realized is important. However, the use of land for this purpose must often be compared with other viable uses the land base is capable of supporting.*
>
> *The role of the Archaeology Branch is not to prohibit or impede land use and development, but rather to assist the development industry, the province, regional authorities, and municipalities in making decisions which will ensure rational land use and development.*
>
> *When the benefits of a project are sufficient to outweigh the benefits of archaeological preservation, the Branch's primary concern is to work with the proponent in determining how the project may be implemented with minimal archaeological resource loss and minimal effect on the development. Where the loss of significant archaeological values cannot be avoided, the role of the Branch is to ensure that appropriate compensatory measures are implemented.*

[13] Ministry of Municipal Affairs, Recreation and Culture, *Archaeological Resource Handbook*, 1990, pages 9-10.

The Fraser Valley contains many prehistoric archaeological sites. In the areas of Delta, Surrey and Langley specifically, some 46 archaeological sites have been recorded by the Branch. The commission considered the location of these sites and found no conflict with the proposed drilling areas at Delta, Murray Creek or Campbell River. The environmental report produced for Dynamic Oil Ltd. and Conoco Canada Ltd. also found no conflict:[14]

> *The proposed sites have also been reviewed from an archaeological sites perspective. None of the sites conflicts with archaeological resources and the B.C. Archaeology and Outdoor Recreation Branch have no objections to the project.*

[14] Regional Consulting, "Environmental Report," pages 27-28.

Staff at the Archaeology Branch stated there is potential for petroleum exploration to also affect unrecorded sites in the Fraser Valley, and as a result any exploration proposal should be subjected to the regular archaeological impact and review process.

This process comprises two principal components: assessment and impact management. Assessment is concerned with the location and evaluation of archaeological resources, and the assessment of impacts during initial project planning stages. Impact management directly follows, and is concerned with managing both unavoidable and unanticipated impacts of site development. The commission sees no problem for the industry in accommodating the concerns of the Archaeology Branch.

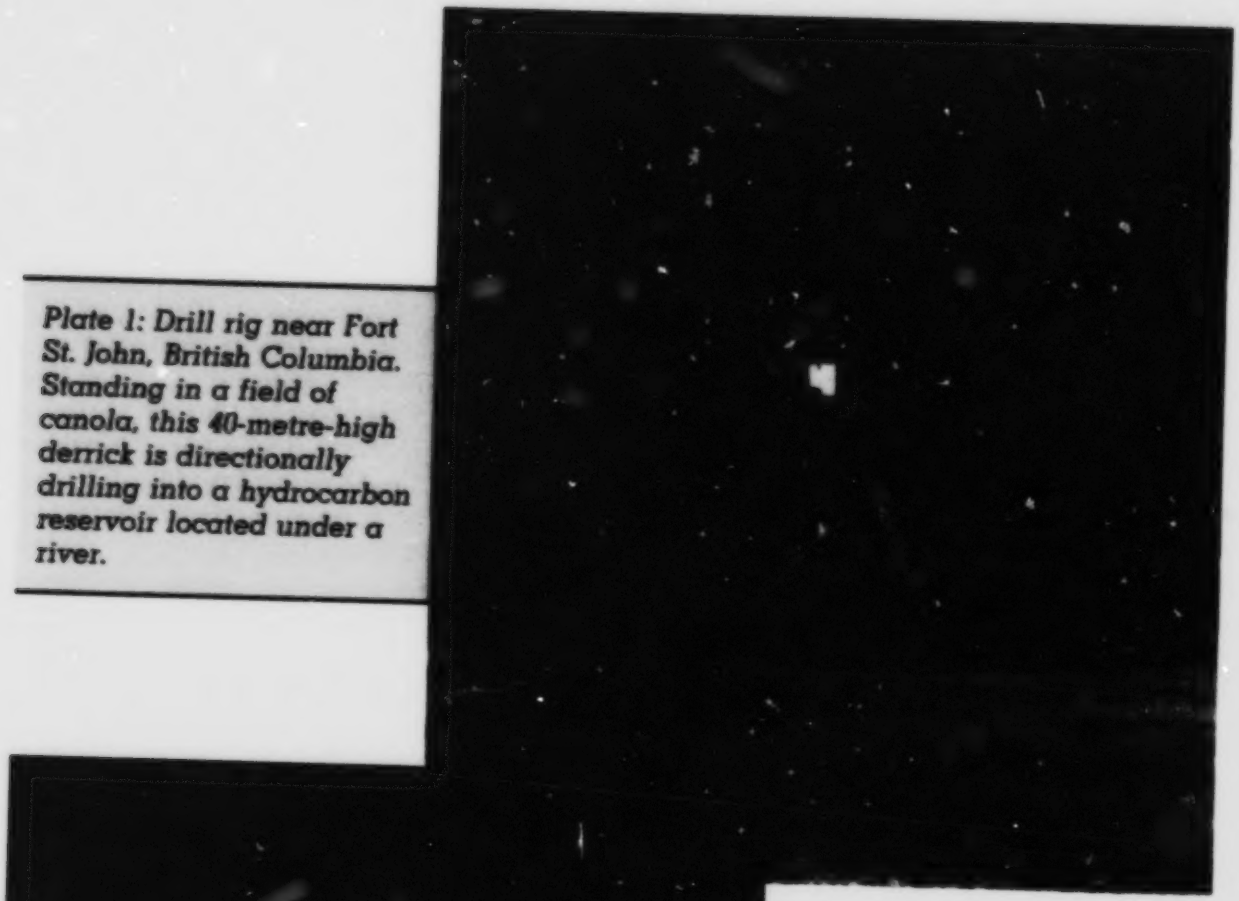

Plate 1: Drill rig near Fort St. John, British Columbia. Standing in a field of canola, this 40-metre-high derrick is directionally drilling into a hydrocarbon reservoir located under a river.

Plate 2: A typical drill site in northeast British Columbia.

Plate 3: Aitken Creek gas storage facility, northeast British Columbia. Operated by Unocal Canada Resources, Aitken Creek is the province's only underground gas storage facility.

Plate 4: Jackson Prairie Gas Storage Project, Chehalis, Washington State. Situated near Interstate 5, this aquifer storage facility occupies 2.5 ha of farmland. Currently, B.C. Gas Ltd. leases 16.67% of the available underground storage space.

Plate 5: Drilling rigs, Long Beach Harbor, California. 60-metre-high building-like structures encase oil production rigs. For aesthetic reasons, Long Beach, Los Angeles, Hollywood and other cities have mandated the use of such structures.

Plate 6: Well shroud, Playa del Rey, California. This 10 metre by 10 metre structure is situated in a residential area where homes are valued in excess of $500,000.

Plate 7: Workover rig, Playa del Rey, California. The home located behind the well site is about 10 metres from the shroud.

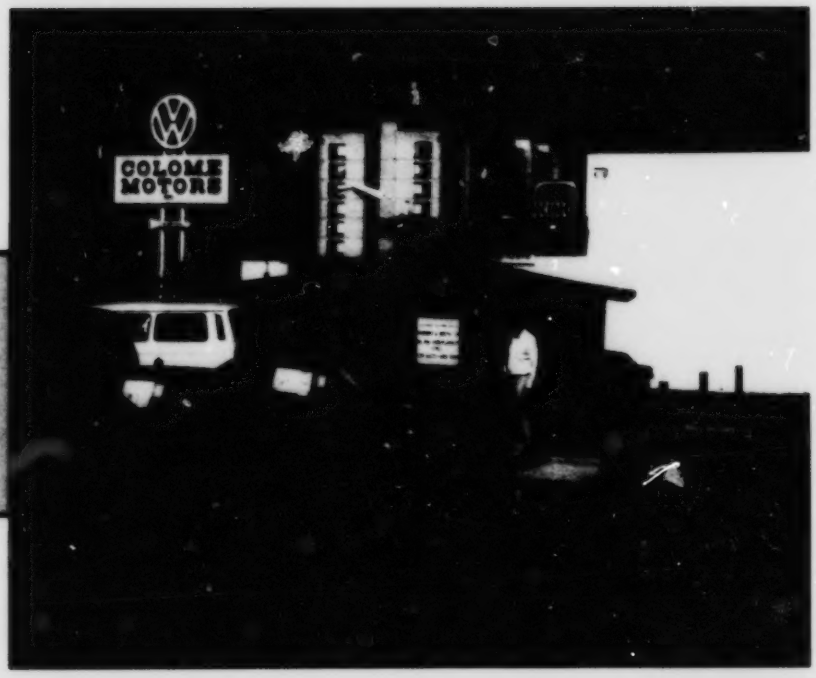

Plate 8: Injection/ withdrawal well, Montebello, California. Located in the local Volkswagen dealership lot, this well is worked over one to two times per year.

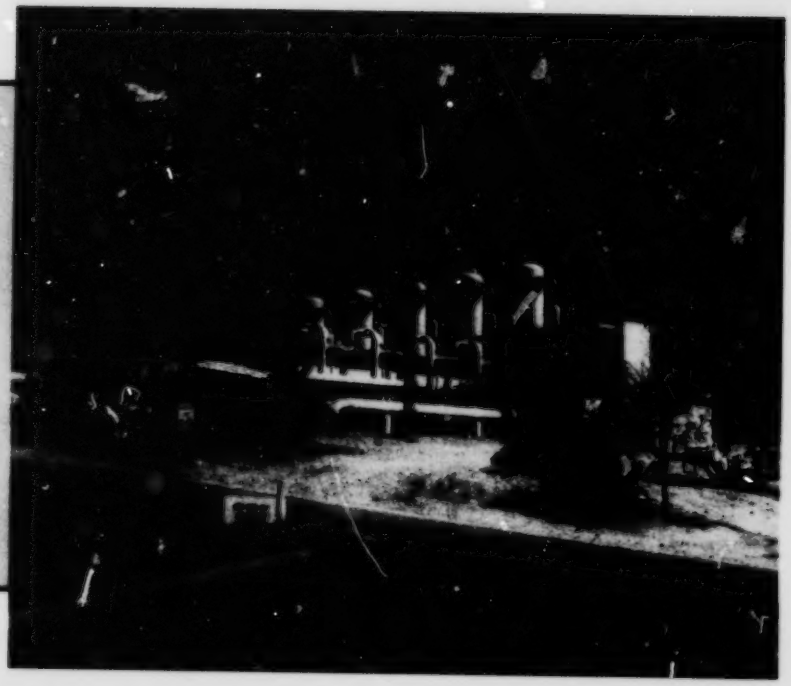

Plate 9: Montebello gas storage facility, Montebello, California. This storage facility, occupying 2.5 ha, is located in a residential area. The majority of wells are directionally drilled from a drilling pad located near the compressor station. Such deviated wells laterally reach targets 2 kilometres from the surface location.

Plate 10: View of the city of Montebello and greater Los Angeles from the edge of the Montebello storage site. $250,000 to $500,000 homes are located within 70 metres of the gas compressor station.

Plate 11: Kalkaska gas storage facility injection/ withdrawal wells, near Traverse City, Michigan. Pinnacle reef carbonate reservoirs provide locales for underground gas storage in northern Michigan.

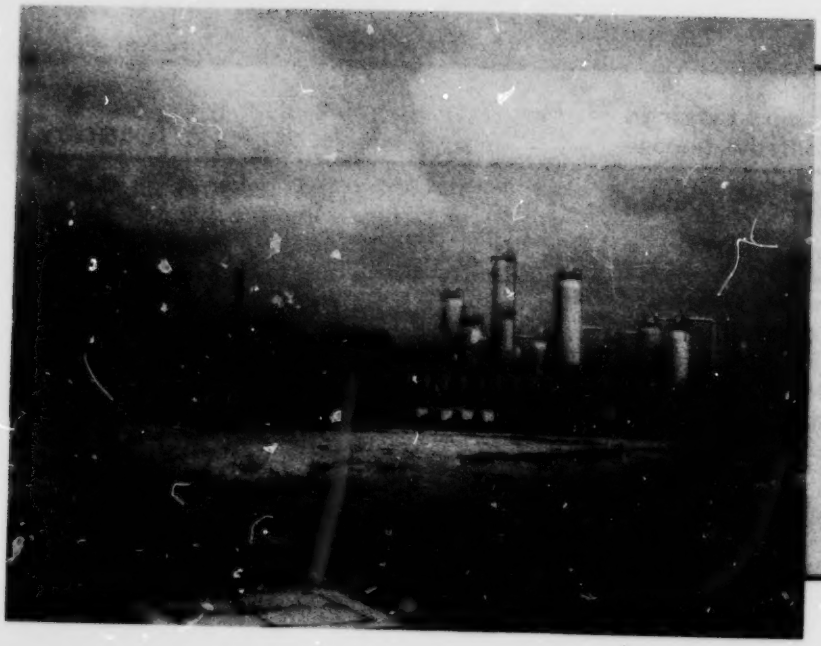

Plate 12: Injection/ withdrawal wells, Chemery, France. Chemery is the world's largest aquifer storage facility, containing 250 Bcf of natural gas. Gaz de France, the operator of the facility, is the acknowledged leader in aquifer storage, and was involved with the creation of a gas storage facility in Quebec.

Plate 13: Injection/ withdrawal well, Beynes, France. This wellhead is located in a rural residential area one hundred kilometres north of Paris.

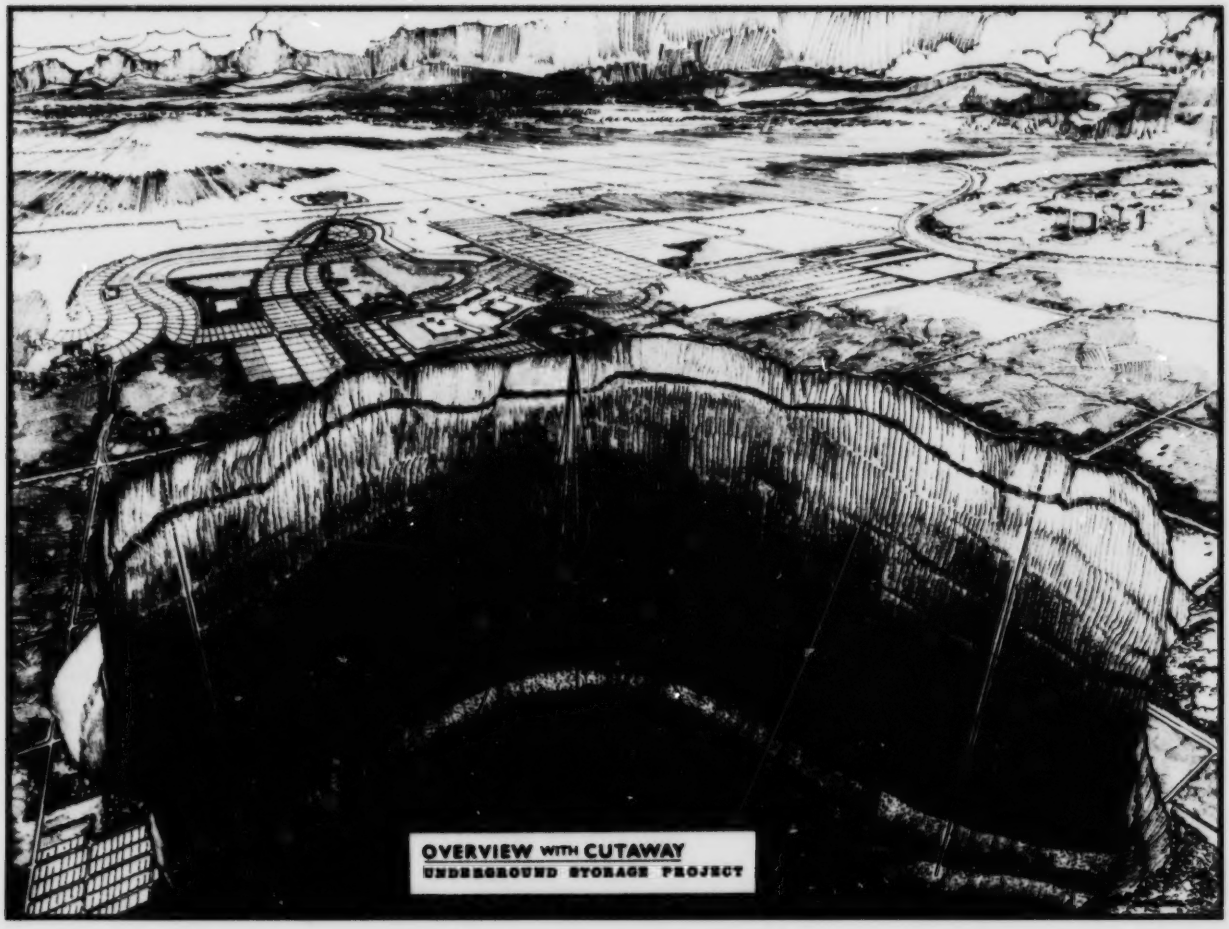

Plate 14: Used with permission of Thurber Consultants Ltd.

General

There is no question that petroleum drilling and subsequent development have sizeable adverse aesthetic effects. Noise, traffic, visual impact, and smell from the industry's operations may all degrade the local environment, and the local residents' enjoyment thereof. Mr. Means in his expert testimony correctly stated:[1]

> *I think from a safety standpoint I could see nothing that would hinder the storage facility. From an aesthetic standpoint, I don't feel qualified to answer that. This is a beautiful area, and I can understand people not wanting a facility from that point of view.*

Much of the citizen concern in the Fraser Valley involved such issues. Their views and concerns in this regard were also the subject of comments by Mr. Gary Runka, of Runka LandSense Ltd., the consultant to the commission on land use in the valley. Mr. Runka described in his report, and both he and Mr. Kirk Miller, the Acting General Manager of the Agricultural Land Commission, outlined in their testimony at the technical hearings[2] the strong resistance of residents in the area to developments perceived as being adverse to the attractive Fraser Valley lifestyle. This concern is entirely understandable.

Noise

Drilling activity can be a very noisy operation when it takes place without any noise suppression equipment. Wind and terrain can also affect noise levels adversely. The question for this commission, however, is not the extent of noise in the absence of design and muffling equipment, but first what can be expected from the exploratory drilling, and second, whether subsequent production or storage can be expected to create such problems that exploratory drilling should not proceed.

The noise levels that can be expected from the exploratory program for the valley has been outlined by the consortium. B.C. Gas' paper (Exhibit T-42, section 14) indicates that, with moderate sound suppression equipment on the rig, the noise level generally will be at 60 dba at 100 metres from the site. The closest residence to the three proposed exploratory well sites is at Murray Creek. This residence is 125 metres from the well site. The noise level at this residence will consequently be under 60 dba, which is within Langley Township bylaws. This noise is expected to continue at each site from three to six weeks.

The consortium also indicated that, due to planned improvements to its noise suppression program through the use of better exhaust silencers and absorptive engine room interiors, it could reduce the noise levels to approximately 50 dba at 100 metres. This equipment would further reduce the noise level at the Murray Creek residence to 49 dba, well within local noise bylaws.

At the Boundary Bay site, the nearest residence is 300 metres from the proposed exploratory well site. The anticipated noise level at this site is approximately 42 dba. The level of existing ambient noise has been measured at 42 to 44 dba.

The program of the consortium thus appears to be designed to be within the ranges of noise currently permitted or existing at residences in the area. Other than as part of a general package of aesthetic design to make the overall drilling program less obtrusive, it would appear to be discriminatory and unfair to

[1] Transcript, page 1524.
[2] Transcript, pages 106–203.

subject this one industrial activity to noise limitations and restrictions that are not imposed on other industrial activities of the Fraser Valley.

An exception to the fairness argument might be by reason of the round the clock nature of the operations. The drilling, however, is expected to be in the spring, or very early summer. Thus noise impact on local residences at night can be expected to be less. Further, the limited length of time involved in the drilling of each well puts this drilling program in a somewhat different category than would be the case were a permanent industrial operation to be established under the same noise bylaws or guidelines.

It should be noted that the noise levels envisaged by the consortium could be further reduced, but costs would quickly escalate. B.C. Hydro, for example, could supply electricity, rather than the proposed diesel electric generating equipment. If it is expected that the noise level will be a problem for local residents, this might be attempted. More likely to be acceptable to both the consortium and the nearby residents, however, would be compensatory payments or other similar inducements by the consortium to nearby residents.

If the government approves exploratory drilling, the noise issue might well be the subject of further negotiation or compensation discussions with the locally affected residents. It does not appear to be a subject for compensation to the area or population as a whole. The prerequisites for successful negotiation and compensation arrangements are discussed elsewhere in this report.

If the exploratory wells achieve positive results, further exploration will likely take place. Under such circumstances there may be some need to vary arrangements made for the initial three wells, by reason of lengthier periods during which the noise would be a factor; however this cannot be determined at this time. Once again, community/consortium discussions may resolve the matter.

However if the exploratory results are positive, and if development and production subsequently takes place, noise from this source need not be a continuous problem. Noise suppression design and the installation of sound muffling equipment can reduce the noise of production facilities to low levels, indeed, if enough money is spent, to very low levels indeed. Again, this matter cannot be analyzed at this time, as there is no knowledge of a host of technical factors that might affect the production facility. Directional (or deviated) drilling, for example, can be used to drill a well beneath a property many city blocks away from the site of the drilling equipment. Plate 14 of this report illustrates how this can be accomplished. Such directional or deviated drilling is more expensive than vertical drilling, and is somewhat more difficult, but it is a useful technique to avoid disturbance.

Further, when these other cost and environmental factors are known, the noise issue is unlikely to be treated as a separate and discrete issue, but will no doubt be dealt with as part of a package of measures to reduce the impact of the production facility. At this point it can be concluded that future noise from a production facility can be brought to within any reasonable community expectation, and that drilling and development experience elsewhere in the world, particularly in urban settings in California and in the urban and rural residential areas of southern England (Poole Harbour), provide adequate models and adequate experience on which to design noise abatement programs for development and production in the Fraser Valley.

If the exploratory drilling is permitted, and if it subsequently leads to an underground storage facility, modern design and sound abatement engineering, combined with sound suppression equipment, can create a system with little adverse noise impact on surrounding residences. Once again, the noise level cannot be reduced to zero,

and once again, the costs may be high, but the knowledge and equipment exists for dramatic noise reductions, orders of magnitude below sound levels of earlier storage facilities.

It is not the purpose of this report to suggest to sound suppression designers and engineers what should be done at some future date, perhaps years hence, assuming that an application for a natural gas storage facility is applied for by B.C. Gas and approved by the government. By then the technology will doubtless be superior to what it is now. However in the course of satisfying the terms of reference of this commission, specifically reference 2 (c)[3] the commission over the summer has visited many underground storage areas in other parts of the world. The commission observed natural gas compressor stations kilometres from the injection/withdrawal wells, compressor stations sunk in the ground, 7 metre earthen berms surrounding compressor stations, natural and plantation forests surrounding the station to absorb and deflect noise upwards, compressor stations with sound deadening walls and ceilings, modified tips of cooling fans, engine mufflers the size of automobiles, and a wide variety of other sound deadening practices. Sophisticated noise suppression technology exists today. If a compressor station for an underground natural gas storage facility is approved in the future for the Fraser Valley, the commission is confident that noise will not be a major concern, provided, of course, that noise suppression engineers are given the money and time to create a low noise system. At this point it can be said that noise of a future natural gas underground storage compressor station is a minor negative factor to be considered when weighing up whether exploratory drilling should proceed.

The commission favours statutory reform in this area based on the Ontario *Environmental Protection Act*. In that province, *EPA* noise bylaws may regulate or prohibit the emission of sounds, make different provisions for different areas of a municipality, make exemptions, and provide for licensing of persons, equipment or premises. Maximum permissible sound levels may be established, and procedures may be set for determining noise levels. *Municipal Act* noise bylaws remain in effect for noises that can only be effectively treated as a subjective phenomenon, like barking dogs and screeching tires.

The Ontario Ministry of the Environment has prepared a detailed model noise bylaw under this provision of the *Environmental Protection Act*.

RECOMMENDATION 21

General Regulatory Approach to Noise Abatement

That in the application of noise abatement regulations and bylaws, petroleum exploration activities should be treated no differently than other industrial activities.

RECOMMENDATION 22

Method of Noise Measurement

That noise levels be measured with approved equipment, by properly trained and qualified personnel, both at standard distances from the noise-generating source, and at the windows of neighbouring residences.

RECOMMENDATION 23

Environment Management Act Noise Bylaws

***That the* Environment Management Act *be amended to make provision for municipal noise bylaws similar to those contemplated by the Ontario* Environmental Protection Act.**

[3] "The Commissioner is directed to enquire into, investigate, review and report on . . . exploration, development and natural gas storage experience in other jurisdictions and areas of a similar nature."

RECOMMENDATION 24

Model Noise Bylaw

That the Ministry of Environment prepare a model noise bylaw for adoption by municipalities.

RECOMMENDATION 25

Noise Suppression Standard

That the Fraser Valley Gas Project Consortium adopt the more rigorous of the noise suppression standards discussed in its Summation to the commission of November 1990, at page 20.

Traffic

The plan of the consortium for the exploratory wells has the drilling equipment transported to each wellsite by trucks. This will require approximately 40 truckloads to move the drilling equipment, which will take place over approximately 4 days. It can be expected, therefore, that at each exploratory well location, 40 loads will be required during the 4 days of set-up and 40 more will be required during the 4 days of removal. Forty trucks constitute approximately 45 minutes of mid-day summer traffic on Highway 13.

In addition, trucks will be used to remove the waste from drill site (primarily rock chips and mud solids) and to transport the wastes to an industrial waste disposal site. Approximately 25 truckloads of waste will be removed from each of the three wells over the six week drilling period. This represents an additional 4-5 truckloads of traffic per week during the drilling period.

The consortium has indicated that these trucks will utilize Highways 1, 13, 10, and 99; 56 and Zero Avenues; 216 and 104 Streets and Old Yale Road, which are primarily provincial roads, and their loads will remain within the existing load limits of those roads. Most of this traffic will be staged during the daylight hours. The consortium intends to limit night time traffic. Further, there would be some traffic in pickups and cars related to the crews, company office, and EMPR personnel coming and going to the drill site.

The commission has made inquiries as to whether the consortium's expectations of truck traffic are consistent with industry experience. The responses have been in the affirmative.

In the commission's opinion, the traffic expectations at the drill sites are within reasonable limits, and will constitute but a minor inconvenience to local residents. If the government gives permission for exploratory drilling to go ahead, some variation of routes, or of times of traffic, may be desired by residents. Once again, provided the decision to proceed with exploratory drilling is final, experience suggests that negotiations between residents and the consortium are very likely to result in a mutually acceptable traffic plan.

Road Damage

Many provincial statutes and regulations and municipal bylaws regulate the operation of heavy trucks and other equipment on highways. Nonetheless, it is commonplace that the movement of such traffic accelerates wear and tear on roadways. This is especially the case where equipment is moved on special permit along roads and the usual maximum axle weight is exceeded. While the paragraphs above suggest that the exploratory drilling program, if it is permitted, will not result in road damage, some mechanism for future dispute settlement on this score may be helpful.

Compensation could be paid directly by the road user for the estimated extra costs caused by the road user's operations, i.e.,

in addition to any of the currently mandated permit fees. Facilitating the negotiation of such payments might be added to the duties of the Mediation and Arbitration Board established by Part 3 of the *Petroleum and Natural Gas Act*. While this Board function would be novel, the Board has demonstrated expertise in resolving other surface rights or compensatory matters to the benefit of the affected parties in a variety of situations in the past. The commission is of the opinion that the expanded role of the Board would be a practical and inexpensive mechanism to assist in compensation negotiations for road damage.

RECOMMENDATION 26

Negotiation of Compensatory Payments for Road Damage with Assistance of Mediation and Arbitration Board

***That direct negotiation of "wear and tear" compensation payments to road maintenance authorities by petroleum industry road users moving oversize loads. This negotiation to be facilitated by expanding the role of the Mediation and Arbitration Board established by the* Petroleum and Natural Gas Act.**

Visual impact

The visual impact of a drilling rig can be expected to be similar to the visual impact of other similar sized permanent structures in the Fraser Valley, such as transmission pylons or microwave towers. The proposed drilling rig is expected to be a triple derrick tower which is approximately 40 metres tall. Factors which will make it more obtrusive are the lights that will burn at night, and the novelty. There is no question but that it will attract attention. Not a great deal can be done to reduce the visual impact of the rig, however the existing topography and vegetation at the Langley Township sites will soften the visual impact somewhat.

If gas is found in commercial quantities, there will likely be a small permanent structure, namely the wellhead and associated equipment. The property required for such a facility will be small, and landscaping will likely deal with most of the visual impact, other than the chain link fence.[4]

If gas is found, further wells will be needed to exploit the field. As described in the spacing section of this report, although current regulations suggest that such wells would be one to every 2½ square kilometres, best engineering practice should supersede such a mechanical and arbitrary rule. The practice of deviated drilling can reduce the number of well site locations required. Thus although a closer spacing might be needed, the impact of such drilling may be substantially less. To be more precise in this area requires a knowledge of the geology of the gas bearing formation, something that cannot be obtained without exploratory drilling.

In addition production or processing facilities for the field as a whole will be required. Such a facility can be expected to cover two hectares. Much of what has been written above with respect to gas storage facilities under the heading of noise would apply equally to production and processing facilities. By digging a below-ground pad before constructing the facility, by building up berms on the boundaries of the facility, by planting trees, and designing the facility to use existing forest cover, the visual impact of a production facility can be reduced to less than the visual impact of a group of farm buildings and their attendant silos, or less than the visual impact of the silos of a cement distribution plant. Again, the limiting factor is cost. How much should

[4] Practice in this regard varies. In some areas (Michigan, northeastern B.C.) there appears to be no requirement for fencing. However in the Fraser Valley, by reason of population density, fencing is considered desirable.

be spent will depend on how far the government requires the petroleum industry to proceed in this activity, or how far the industry voluntarily decides to go. However ultimately the equity question of how much the petroleum industry should go beyond what is required of other industries must be addressed.

If gas finds do not take place, but instead, a favourable geological formation for a storage facility is discovered, some fifteen to eighty injection/withdrawal wells can be expected, along with another ten to twenty observation wells. This is a substantial amount of drilling, concentrated in an area which may be 10 to 15 square kilometres in size.

Smell

The smell of gas is another potential aesthetic problem. Gas facilities, particularly those established some years or decades in the past, can be expected to have some loss of gas from the system. Small gas leaks from joints, valves, flanges and other such equipment are common. Thus a single wellhead may have a dozen or more potential sources of leaks.

The amount of gas that leaks to the atmosphere from gas systems is not great over all.[5] It does not constitute a major hazard to air quality, or to the upper atmosphere. Although methane is a greenhouse gas, the emissions of which contribute to global warming, the amount that comes from leaks in the North American and Western European gas production, storage, and distribution systems is minor compared to the amount of methane that gets into the atmosphere from humans and other animals (particularly cows and other ruminants), from methane produced in municipal landfill sites, and from swamps and other natural causes.[6] Further, the amount of gas that leaks from gas transmission, storage, or distribution systems is no threat to human health, provided always that the gas is not of such concentrations as to reduce oxygen content of the local atmosphere to below minimum required levels. Even for those with respiratory problems, methane is highly unlikely to create any serious physical discomfort.

The problem comes from mercaptan or other additives which are combined with the gas in very low quantities to give it odor. This product is immensely effective; only a few teaspoons of mercaptan will odorize all the gas used in the average home for a year. Not surprisingly the smell of mercaptan can, and sometimes does, create an aesthetic problem downwind.[7] It is assumed that mercaptan will be added to any gas in storage, to odorize the gas in case of a leak.

Despite far greater integrity in joints, flanges and valves, and other pipe connections that can be expected today than in the past, and far more sensitive measuring devices to detect leaks, there is little question odor problems can be expected from time to time. Nevertheless it is unlikely that these odors will extend horizontally far beyond the perimeter of the gas plant, and it is further very unlikely that such odor problems will continue for long periods of time. Natural gas is lighter than air. It is therefore likely that the rising gas from a leak will carry the odorant into the atmosphere.

The commission concludes that the establishment of an underground natural gas storage facility can be expected to cause some odor problems from wellhead facilities. It further concludes that this is unlikely to present long term or serious problems to nearby residents. This is a

[5] The exception to this statement is Eastern Europe, where some old transmission and distribution systems together lose up to ten per cent of the gas that ultimately reaches the consumer.

[6] When discussing losses, it should also be borne in mind that there are certain losses from flaring. In British Columbia, the amount of gas flared for one reason or another but mainly for safety reasons, is slightly over one per cent. Most of this is in the field, at the one thousand production sites.

[7] Hydrogen sulphide (H2S) in sour gas can also create a smell problem. This is unlikely to be a problem in the Fraser Valley. The aesthetic effects of sour gas are discussed elsewhere in Chapter 9 under the heading of property values.

factor that should be addressed in more detail if and when an examination of a proposal by B.C. Gas is considered by the B.C. Utilities Commission, at which time information on wind patterns, distance from the facility of residences, and other site specific details will be available.

Potential odor problems are site specific and limited in extent. With good housekeeping and the expenditure of some money on good technology, they can be reduced to very low levels. Further, they are likely to be far less offensive to neighbors than the smell of a pig farm, or other such agricultural operation. They are a minor aesthetic factor when considering whether to proceed with exploratory drilling.

With respect to possible commercial production of gas, the commission notes that such gas is not odorized until processed, and the gas that might come from the ground is very unlikely to have any hydrogen sulphide (rotten egg) smell. It expects very little, if any, smell problems to be associated with production, except at the odorizing station.

To be noted as well is the fact that the Fraser Valley has had a long experience of odorizing gas. Before exports can be carried in an American pipeline, the gas is odorized, as is gas for B.C. use. Thus very substantial odorizing operations are currently taking place. Any possible storage facility would only slightly increase the current odor risks.

Petroleum Facilities in Other Jurisdictions

Subsection 2(c) of the commission's terms of reference requires the commission to investigate and report on the exploration, development and natural gas storage experience in other jurisdictions.[8]

Facilities Not Visited

This was done in two ways. First, by correspondence and telephone. For example, information from Sweden, Germany and Holland was obtained this way. Sweden is in the midst of an examination of the storage issue not dissimilar to the process of our own in British Columbia, and at the same time is embarked on a drilling program for natural gas at depths never before attempted.[9]

The quality, safety and environmental impact of Germany's natural gas industry is dramatically varied, depending on whether the facilities are located in the former East Germany or whether located in the former West Germany. In total there are thirty-two underground natural gas storage facilities in the country, eight of which are in aquifers, sixteen are cavern facilities (with a combined total of one hundred and eight caverns) and, finally, eight are in depleted gas fields. There are ten more under development or in the planning stage. There are no special approval procedures for such facilities in populated areas other than the normal industrial safety rules. The facilities are in or near many German cities, including Munich, Hanover, Hamburg, Darmstadt, Berlin and Kiel.[10]

Holland is a major producer of offshore gas from the Groningen field, supplying, for example, twenty-eight per cent of German requirements last year, and similar amounts of French consumption.[11] The lack of storage facilities in Holland, given the extensive domestic supply, is as expected. It has been suggested elsewhere in this report that if the Fraser Valley

[8] The Commissioner is directed "to enquire into, investigate, review and report on . . . exploration, development and natural gas storage experience in other jurisdictions and areas of a similar nature."

[9] Telephone conversations between Stockholm Gas officials and Commissioner, 19 and 22 August, 1990.

[10] Correspondence between the Commissioner and W.E.G. Wirtschaftsverband Erdol-und Erdgasgewinnung E.V., dated 9 November 1990.

[11] Telephone conversations of Commissioner with Ms. Anneke Schutter of the Embassy of the Netherlands, Ottawa, late October, 1990.

provides a field with commercial quantities of gas, the storage question may become moot. Particularly interesting is the fact that Germany, adjacent to Holland, many of whose major cities are within two hundred kilometres of the Dutch field, nevertheless has embarked on a vigorous storage program. Similarly France, whose major population centers are only one or two hundred kilometres further, and which similarly receives large amounts of Dutch gas, also requires extensive storage capacity.

The conclusion for British Columbians from this proximity of storage facility and supply is that even with consumer populations half the distance of the Peace River to the Lower Mainland, the Europeans have made the decision to create, and now expand, underground natural gas storage. The proximity of the Dutch field has not provided the buffer, a natural storage facility, to augment Algerian, Norwegian and Soviet supplies during the period of high winter consumption. Further, it appears that the gathering and conservation problems associated with fluctuating deliveries have encouraged the Dutch to opt for steady gas production rather than the fluctuating production that would be the case if their field was used only in winter by the neighboring consumer countries.

The process of obtaining information through correspondence could have been expanded many fold. Other European countries, Australia, and Japan all have natural gas production or storage facilities, or have considered the storage option. All are possible sources of information, many being mentioned in the public meetings or technical hearings. The limited time available to the commission prevented a fully comprehensive survey. The result was concentration of effort on the industry leaders, such as Ontario, Alberta, the United States and France.

Facilities Visited

The second method of obtaining such information was site inspections. This began with a visit to Drayton Valley Alberta. Later the commissioner and commission staff visited France, Italy and Britain, Washington State, Oregon, California, Michigan, Illinois, Kentucky, Missouri, Ontario, Alberta and the Peace River, plus the 1986 Nanaimo drill site of British Petroleum and abandoned drill sites in the Fraser Valley itself. These visits were very important to the commission process. The length to which our our hosts were willing to go to make these trips informative and useful to the commission was quite remarkable, and greatly appreciated.

The facilities visited and their locations are contained in Appendix G of this report. A listing of all that was seen at these facilities would be lengthy. In some other chapters of the report the lessons they provide for the Fraser Valley have been discussed. This section will provide a brief overview.

Before commencing this inquiry, the Commissioner, like most southern British Columbians, generally associated petroleum industry activity with remote or less populated areas of the world such as the deserts of the Middle East, the tundra of Alaska, rural Texas, Louisiana, Alberta or the comparatively[12] sparsely populated Peace River area of this province. Petroleum activity of course took place elsewhere; California, for example, provided this province with virtually all its petroleum requirements for more than half a century. However the coexistence of petroleum production and human populations is assumed by many British Columbia residents to be an exception to the rule.

This attitude was noticeable during the commission's public meetings. Residents would regularly state that they were not opposed to the industry, and not opposed to underground natural gas storage in principle; what they objected to was having it in the Fraser Valley. The industry did not belong in a populated area.

[12] The comparison is with the Lower Mainland.

A trip to the Sarnia region of Ontario in early summer illustrated the compatibility of farmland and an underground natural gas storage facility. The Tecumseh storage facility which was visited is very important to the Ontario natural gas system.[13] Above it are some eighty farms, which vary in size but average about forty hectares. The farmland is of high quality, and expensive. Consumers Gas owns about 10% out of the 3,500 hectares which overlie the facility. The purpose of such ownership is to prevent other industrial activity, and to maintain the rural character of the area. There appears to be no conflict between the facility operator (Consumers Gas) and the rural population. The purchase policy of Consumers Gas keeps agricultural land prices in the area higher than they otherwise could be expected to be.

The trip to Long Beach and Los Angeles, California revealed a different picture. The Los Angeles Basin is one of California's largest petroleum producing fields. Petroleum exploration has even taken place, with deviated drilling and with a building shell disguising the rig, in downtown Beverly Hills. A visit to the waterfront in Long Beach revealed many petroleum rigs, in the docks area as well as in commercial and residential zones. Artificial offshore islands immediately in front of the beach from which Long Beach gets its name housed drilling rigs, storage tanks and other petroleum facilities. These were screened with various structures and trees, which masked the facilities, even the drilling rigs, from view (Plate 5).

Two underground natural gas storage facilities were visited in Los Angeles, both over expensive residential areas. Injection/withdrawal wells were located in the yards of apartment buildings, in used car lots, in parks, and on residential lots. A photograph of one such injection/withdrawal well is found at Plate 8. Drilling rigs, with a fence of telephone poles surrounding them, on which were draped sound absorbing pads that looked like the aerobic mats of the Jolly Green Giant, were well within a hundred metres of the windows of nearby condominiums.

The conclusion drawn from the Californian trip was that urban populations and the petroleum industry can co-exist in the southern California setting. However, the industry was there long ago, in many cases before the subdivisions and development. Apart from demonstrating that there is no inherent incompatibility, California does not provide a model for introducing such industrial activity into the Fraser Valley.

The visits to petroleum facilites in France, Italy and England allowed the Commissioner to appreciate the problems associated with introducing the industry to rural, semi-rural and urban areas which previously had no experience of it.

The Italian underground natural gas storage facilities were visited in mid-August. One of the areas visited (with two underground natural gas storage facilities) is flat and very fertile river bottom land, essentially rural, with small villages and farms above the storage facilities. Corn is the major crop. As in California, France and Britain, the colours of the facility were chosen to merge with the local landscape. Treed areas assisted in concealment. The day that the facility was visited was the Feast of the Assumption. The most noticeable noise when standing inside the fenced gravel pad of the storage facility was the tolling of bells from the village church about seven hundred metres away, calling the faithful to the feast day service.

No doubt there are times when the noise impact is reversed, and the church hears the compressors of the the storage facility, rather than the storage facility hearing the bells of the church; however the degree of integration of the facility into the rural landscape was quite remarkable. This was a far, far cry from the out-in-the-open and spread out facilities of Alberta or the Peace River, or for that matter, the storage

[13] Testimony of Ivan Cuthill, Transcript, page 1255 ff.

facility of Jackson Prairie in Washington State. The integration of the facility into the landscape is not simply marginally better; it is orders of magnitude better.

France provided similar experiences. To say that the French countryside is attractive is like saying Joan Sutherland can sing. The statement is true, but hardly conveys the full picture. Integrating industrial facilities into such a countryside presents major problems.

The landscape near the facilities visited was again rural, although at one facility rural/residential would correctly describe part of the surface area above the storage facility. In France the population levels appeared to be somewhat less than that of the Italian facility described above, and the farmland more rolling hillside than flat valley plain. The underground storage facilities were unobtrusive, and well blended into the surrounding area. Noise was considered the most difficult problem, but even so, was not regarded as particularly serious. At one facility a spill of mercaptan had taken place, which, not being mixed with natural gas, had not been carried upwards into the atmosphere. This had created a temporary odor problem for nearby residents.

From the point of view of intergration into the landscape and low aesthetic impact, the Wytch Farm oil field (Figure 15) near Poole in southern England was the most striking of the facilities visited. The area is a tourist destination and retirement center, and is listed by the British Government as an Area of Outstanding Natural Beauty, adjacent to both Sites of Special Scientific Interest and National Nature Reserves. The fleet of yachts at moorings in the harbour (Britain's largest protected water area) rivals those of both Victoria and Vancouver. From a land utilization and sensitivity point of view it is perhaps the most different area one could find from the North Slope of Alaska, or the deserts of Libya or Saudi Arabia, or, for that matter, the Peace River country of northern B.C.

[14] Eighty thousand barrels a day.

Despite the area's sensitivity, in the past few years British Petroleum has established Western Europe's largest[14] on-land oil production facility in the area. Very little is visible. The design of transportation corridors, deviated drilling, the use of screening trees and shrubs such as rhododendron, excavating pads for facilities with raised berms on their perimeter have virtually hidden the facilities. Even military camouflage netting has been used to shield views of the facility while vegetation was growing.

Much of the facility is located on 300 metre by 600 metre Fursey Island in Poole Harbour. The facilities occupy approximately one sixth of the surface area and are virtually undetectable from the waters around the island. Despite being the centre of a major industrial undertaking, the island is also home to one of the last remaining colonies of the British red squirrel. Golden pheasants and other birds were noticed at the edges of the fields and woods. With the exception of the industrial pads themselves, the island is a country park. The efforts made went far beyond the masking of the visual impact of the facilities as in California, and instead entered the realm of sophisticated English landscape architecture in the tradition of Capability Brown. A visiting British Columbian cannot but think of Mrs. Jenny Butchart, who turned an eyesore industrial quarry into one of the province's loveliest gardens. The results are different; Fursey Island is not the Butchart Gardens. However, the same spirit and vision is present in the work of the landscapers commissioned by British Petroleum.

The conclusion to be drawn from the Wytch Farm field is that if the determination is there, the design is done properly, the work is carried out effectively, if money is available, the impact of petroleum facilities in a rural/residential area can be reduced dramatically, to the point where it is far

less obtrusive than most other industrial activities.

In short, the experience elsewhere has altered the Commissioner's early summer perception of drilling natural gas and production from activities that belong away from populated areas to an industry that can be located, with proper care and attention, in any setting; wild, rural, rural/residential or urban. To judge the effect of the industry in a populated area on the basis of experience in the Peace River would be a mistake. More appropriate examples of industry integration into rural, rural/residential and urban settings exist.

The 1986 Nanaimo Drilling Program

In June 1986, BP Canada and two B.C. firms, Cassidy Resources Ltd. and Laurel Explorations Ltd., commenced a $2.5 million gas drilling program near Nanaimo. Brinkerhoff Drilling Canada was contracted to perform the drilling work. The program consisted of drilling two wells in Cedar, which is a rural agricultural area south of Nanaimo. The first well was the Laurel Harmac well, which was drilled to a depth of 1,400 metres in 25 days. The second well was the Laurel Yellow Point well, which was drilled to 1,574 metres in approximately 30 days. Neither well produced signs of oil or gas, and the program was halted at the end of August 1986.

The Commissioner and the commission's Technical Advisor, Mr. Tony Fogarassy, visited the sites in July of 1990. Despite detailed maps provided by EMPR, and the fact that in the case of one well site the crop had recently been removed, they were quite unable to locate the well hole. The other site was in a field of growing crops, which could not be searched without crop damage. Inspection from the edge of the field did not indicate the location of the well. Some stumps pushed to the vacant land at the edge of the cultivated land may have been associated with the drilling, but that appears unlikely, as the well site was in an already cleared field. In short, the rehabilitation of the wellsites by BP and its contractors appears to have been entirely successful.

An adjacent property owner was talked to who was a resident at the time of the drilling. He stated that there had been some noise (the drillsite was about 150 metres from his house) but with the windows on that side of the house closed, the noise was not excessive. He was generally happy with the operation. The company had provided him with a 80 litre a minute, 150 metre well as compensation for the inconvenience he had suffered.

In October, the commission carried out further inquiries into the impacts of this program on the residents of the Cedar area. In a review of press clippings from the Nanaimo Daily Free Press from May through August 1986, the response to the drilling program by area residents appeared to be positive. Press accounts referred to excitement in the Cedar area, and the potential for immediate and long term employment for residents. In general, most of the newspaper articles during this period provided factual information on the drilling program itself, and technical information on oil deposits, the drilling process and safety requirements. Press coverage in this regard differed from much of the coverage in the Fraser Valley press during the life of the commission.

In the review of press accounts, the commission found only one reference to an individual expressing concerns about the drilling program. Prior to the commencement of drilling for the first well, the owner of Five Cedars Poultry Farm, Mr. Bob Devji, expressed reservations over the impact of drilling on his operations which were adjacent to the drilling site. Mr. Devji's main barn was located 300 metres from the drilling rig. In

particular, Mr. Devji was concerned about lighting, noise, and the quantity and quality of his well water.

The commission contacted Mr. Devji at Five Cedars Poultry Farm, and inquired into the impacts of drilling on his farm. Mr. Devji indicated that the noise and lighting from the 24 hour drilling had some negative impact on egg production from his chickens, in that egg production declined both during and for approximately one month following the drilling activity. The water well was unaffected.

Although Mr. Devji indicated some negative impact from the drilling activity, he was generally pleased with the program. The companies took steps to minimize the noise impacts, and also offered compensation for adverse impacts on the poultry farm. Mr. Devji did not request compensation for reduced egg production, indicating that the adverse impact was not a matter of major concern.

FIGURE 15 — An example of screened petroleum facilities in surroundings not unlike the Fraser River Delta area. Wytch Farm field, Poole, England.

Underground Natural Gas Storage — Surface Property Values

Among the various economic concerns expressed at public meetings in the Fraser Valley was the possibility of surface property value declines were exploratory drilling to take place. Further, concerns were expressed that underground natural gas storage would reduce property values of those properties above or near the surface boundaries of such a facility.

With respect to underground natural gas storage, the same concern has been expressed in other parts of the world before storage commenced. Of particular note in this regard is the Laclede field near St. Louis, Missouri, which the Commissioner had occasion to visit.

The Laclede Field

The Laclede natural gas storage field was developed in the early 1950s, the first deep well being drilled in June of 1953. The first gas was injected into St. Peters sand at approximately 450 metres depth in 1955. The field contains approximately thirty billion cubic feet of gas, of which two thirds is cushion gas, and one third working gas. It utilizes some 50 injection/withdrawal wells, and 28 observation wells. The area in question is in north St. Louis County and south St. Charles county, and underlies approximately 4,000 hectares, some 25 kilometres north of downtown St. Louis. It is a prime rural/residential area within easy commuting distance of the city.

The project was not popular with many of the local residents, most if not all of whom owned the subsurface property rights. They formed an association, and fought the project vigorously, at the political level, in the press and in the courts. One of their major concerns was that surface property values would be depressed. Ultimately, (after approximately two years) expropriation proceedings (termed condemnation proceedings in the U.S.) succeeded, and the ownership of the subsurface rights was taken from the approximately five per cent of the owners who had refused all offers made to them by the Laclede Gas Company.

As mentioned, the battle over the establishment of the field was long, bitter, and well publicized. The claim of the opponents of the storage area that surface property values would be depressed proved, in the short run, to be true. Thanks to the publicity, and the high level of public concern engendered by the claims of high risk, surface property values declined relative to property values of similar properties not over the storage facility, and remained depressed for approximately two years after the facility began operating. Thereafter, as property buyers became accustomed to the facility, surface property values returned to values similar to those of other similar properties not over a storage facility.

California

The Commissioner and commission staff visited many other underground natural gas storage facilities. Some, such as those visited in Los Angeles, California, were below urban residential developments, where lot size appeared to be in the neighborhood of 0.1 of a hectare, and where the value of the house and lot was between a third of a million and half a million U.S. dollars. Some of these houses were within sight of the compressor facilities, and approximately 200 metres away. Others were within 100 metres of the station, but hidden from it by a small ridge. Still other homes had injection/

withdrawal wells concealed by gazebo like structures on adjacent landscaped lots. Plate 8 is a picture of one such gazebo.

Inquiries as to property value depreciation did not meet with uniform replies. Some residents close to the compressor stations mentioned noise or odor, which in their view would have a depressing effect on land values, although no figures were given to back up these opinions. The presence of injection/withdrawal wells in subdivisions, by contrast, were generally welcomed as adding to property values; the subdivision as a whole was more attractive by reason of the landscaped small parks that surrounded the gazebos, which in turn concealed the wells. Commercial properties with injection/withdrawal wells apparently had no alteration in property values. The structure was accepted in the same manner as electricity utility company transformers would be here.

Other Jurisdictions Visited

The effect on urban, suburban, or rural residential property values in other areas visited appears to have been similar. Once the facility was established, property values reflected the actual situation. Noise, or smell, or visual impairment views reportedly had an impact on values. Where such conditions did not exist, there was no reduction of property values. Indeed, the presence of the petroleum industry as a potential purchaser of property (for homes of its employees as well as for facilities) was mentioned as a factor that increased property values. The existence of a gas storage facility underground *per se* appeared to have no depressing effect on surface property prices in any of the areas visited by the commission.

In rural situations, the effect of the industry appeared to increase surface property values. This was true whether in the United States, Ontario, France, Britain or Italy, although in the latter two countries, particularly France, the government appears to encourage the gas industry to pay top dollar as an indirect subsidy to the rural economy by the urban consumer.

The main reason for property value increase in all these jurisdictions was the apparent willingness of the petroleum industry to pay above market prices for property required for facilities. This has resulted in an upward pressure on prices generally. Further, the willingness of the industry to pay a disproportionate amount of its share of local taxes, and its willingness to undertake voluntary expenditures on general infrastructure of use to other local residents, has led to increased surface property values for other residents. Finally, the willingness of gas companies as a goodwill gesture to provide gas to small rural communities which conventional economic analysis would consider too expensive to supply, is another reason for rural property prices to be higher where the industry is active.

Alberta

The commission received from the Energy Resources Conservation Board of Alberta two specific Alberta studies on the effects of petroleum industry activities on property values. Messrs. Nichol and Morin of the ERCB also provided perceptive analysis of these two studies.[1] The commission considered commissioning such a study for the Fraser Valley, but rejected the idea by reason of the high level of uncertainty surrounding the project, and the lack of data available.[2]

[1] Transcript, page 895 ff.

[2] There have been few local newspaper articles on the issue. In one, a realtor complained that a client had backed out of a deal by reason of the possibility of natural gas storage in the Fraser Valley. In another, the realtor interviewed indicated that prospective buyers were showing an increased interest in purchasing by reason of the possibility of profit from subsurface rights.

The two November 1988 Alberta studies, by Jim Lore & Associates of Calgary and Deloitte, Haskins & Sells of Edmonton[3] indicate that without some data from actual sales, such studies cannot be effectively undertaken. In the Pincher Creek region, residential recreational property sales were insufficient to enable Deloitte Haskins & Sells to come to a conclusion.

It should be noted that the Alberta studies concerned sour gas facilities, which can be expected to create much greater public concern by reason of the poisonous nature of hydrogen sulphide than the exploratory drilling proposed for the Fraser Valley, or for any subsequent developments that might result from exploration in the Fraser Valley. Further, the scale of the Caroline development (subject of the Deloitte, Haskins & Sells study) must be borne in mind. It is very large indeed, involving the expenditure of 800 million to a billion dollars.

Caroline Swan Hills

The first and second paragraphs of the Deloitte, Haskins & Sells report outlines the purpose of the study. They read:[4]

> *This study was initiated as a result of the proposed development of the Caroline Swan Hills Gas Field. The development of this field has been somewhat controversial because the natural gas in the field is sour, containing a high percentage of hydrogen sulphide. One of the concerns of local residents is that the development of this sour gas reserve will have a negative impact on surrounding property values.*
>
> *The purpose of this study was to identify and measure the effect of sour gas facilities on rural property values. . . .*

The conclusions of the study can be found in full in Appendix L. The quote below indicates their drift:

> *Overall, it is concluded that the presence of sour gas facilities had no effect on property values in general.*

West Central Alberta

The purpose of the Jim Lore & Associates study is outlined in their introduction.[5] It states:

> *This study compares land sales in specific areas to answer this question: Does the presence of sour gas facilities, including well sites, pipelines and/or sour gas processing facilities, have any effect on the value of property?*

The Report concludes:[6]

> *The price of properties with sour petroleum facilities on or near them falls within the normal variability of the data for both agricultural and residential land.*
>
> . . .
>
> *In summary, the presence of sour petroleum facilities has not affected land prices in the past decade in the Caroline area.*

Again, it must be noted that the Alberta studies were for sour gas facilities, which present quite different risks to those associated with sweet gas. Public concerns logically should be considerably higher where sour gas is concerned, and property values should reflect that greater concern.

The Fraser Valley

To return to the Fraser Valley, opponents of drilling who claim that the fear of underground natural gas storage may

[3] Commission Exhibits T-39 and T-40.
[4] Exhibit T-39, page 2.
[5] Exhibit T-40, page 1.
[6] Exhibit T-40, pages 17-18.

depress surface residential property values are probably correct in the short run. Just as long as the fear exists, there will be some potential purchasers who decide that the possibility of gas storage creates an uncertainty which they wish to avoid. Were a facility to be established, however, there is no reason to suspect that the pattern of land values would be any different from those experienced elsewhere, and outlined in some detail above in the case of the Laclede field of Missouri.

The extent of this depressing effect on surface land values is clearly the perceived fear of underground natural gas storage, not the existence of underground natural gas storage itself. Thus predictions of future depressed surface land values by opponents of drilling are likely to be self-fulfilling, until proven wrong by local experience with the underground natural gas storage facility, assuming that such a facility is ultimately established.

Exploratory Drilling and Production

Surface Values

With respect to drilling as opposed to underground natural gas storage, the same principles apply. Drilling does involve noise, lights at night, truck traffic, and visual impairment of the view or skyline. This can be expected to continue at each well site for between three and six weeks, twenty-four hours a day. The effect is not unlike around the clock construction activity. When it is in progress it will undoubtedly have an effect on the enthusiasm of a potential buyer of a nearby property.

When the drilling is completed, however, the situation will change. A dry hole is plugged, the area landscaped, and very little trace of the activity is likely to remain. The site of the wells drilled by BP south of Nanaimo in 1986, for example, are hard to locate, even with detailed maps, and show no signs of ground disturbance.

A producing gas well will likely — although not necessarily — have an above ground structure, but it is unlikely to have an effect on a neighboring property any greater than any other similar sized structure.

A return of a drilling rig, for workover purposes, can be expected from time to time, but this is not likely to have serious impacts. The Commissioner observed a workover drilling rig at work ten metres from the windows of a neighboring $400,000 house near Marina del Rey in California, which continued to be inhabited during the workover process. At least four other properties were within a hundred metre radius of the workover rig. B.C. regulations for the Fraser Valley require not ten metres distance from a building, but one hundred. Thus, when drilling is completed, whether or not gas is found, it is unlikely to continue to have any effect on property values locally.

Subsurface Property Values

The paragraphs above deal with possible surface land values. The situation is quite different for subsurface land values. It should be borne in mind that more than half of the property owners outside of urban areas in the Fraser Valley also own subsurface rights.

The effect of petroleum company exploratory activities on subsurface property rights can be expected to be positive, as petroleum companies buy these rights which up to now have not entered seriously into property valuations. The arrangements made between private subsurface property owners and the consortium or other companies have not been made public; however it is well known that the sales of government held lease, licence and permit rights totalled $5.5 million. The amount of money involved in exploration can be substantial.

If a commercially exploitable find is made, the value of these subsurface rights may increase substantially. A 100 Bcf field would be worth roughly $200 million to all rights owners (including the government).

A field of that size is within the expectations of the consortium. The gas field may extend to fifteen square kilometres, and all property owners will receive payments in proportion to the subsurface rights that they own. In other words, the profits will not only accrue to the farmers or landowners on whose land the five or six wells required to exploit the gas field are located, but to all other property owners with subsurface rights. The reaction of these people to a government decision to expropriate or otherwise render their subsurface rights worthless, with the consequent denial of this potential income, is commented on elsewhere in this report.

Were no commercial quantities of gas to be found, but a storage formation located, the subsurface rights owners' legal position under current British Columbia law has not been tested in the courts. Suggestions regarding improvements in the British Columbia legislation appear elsewhere in this report. However, it can be assumed that they would benefit by substantial rental payments, however arranged.

Overall, the impact of petroleum industry activity in the Fraser Valley on values of properties with subsurface rights attached can be expected to be upward and very positive. If commercial quantities of gas are found, in some agricultural areas the impact could double existing land values. The effect can be expected over the total surface area above the field, which may extend for many square kilometres.

Liability of Real Estate Agents

At a number of public meetings, the fear was expressed that real estate agents would be legally liable for failure to inform potential buyers of the risks of a future natural gas storage facility beneath the property in question. While anticipating court decisions always involves an element of speculation, this fear appears to be groundless. For a real estate agent to be liable for failure to disclose a physical risk, the risk must be tangible; further, damage must have occurred.

Our court system is built on the principle of precedent. Where there is little or no local experience, our courts can be expected to examine the experience of other jurisdictions which have faced the same or similar questions. Past experience with underground natural gas storage facilities worldwide, particularly with those established with modern technology, does not support the contention that there is any appreciable risk to residences, or residents, living above such facilities.

With respect to the impact of a possible natural gas storage facility on property values, discussed above, the situation is exactly the same as with any other possible future threat to property values. The real estate agent would be in the same legal position with respect to divulging possible future short term depreciation of the property's value by reason of concern over a natural gas storage facility as he or she would be in the case of divulging to a possible purchaser his or her knowledge of a possible penitentiary, or of possible highway construction, nearby. There is nothing unusual or unique about a natural gas storage facility in this regard. With respect to property values and a real estate agent's obligation to inform a prospective purchaser, it is simply another of the many hundreds of factors that might affect future property values adversely — or positively. How far the maxim "let the buyer beware" applies, and what is the legal obligation of the realtor to divulge, are matters for industry codes of ethics, and of specific government legislation for the real estate industry.

Location and Surface Land Ownership

An issue that came up repeatedly during the public meetings was the location of underground natural gas storage facilities.

The thrust of the argument of those raising this issue was twofold: first, that no underground natural gas storage facility should be established under populated areas, and second, that the operator should purchase all the surface land above the underground natural gas storage facility. Support for these positions was declared to be a section headed "Safety and Risk", found in Chapter 14, pages 584 to 588 in a textbook by the late Dr. Donald L. Katz and Dr. Robert Lee of the University of Michigan, entitled *Natural Gas Engineering*.[7]

It should be remembered that this is a textbook for engineering students, not a monograph or technical article. Textbooks are written with educational purposes in mind, and are designed to give a framework understanding of general concepts. The passages in Drs. Katz and Lee's book are not analyses of specific underground natural gas storage proposals, and were certainly not written with the Fraser Valley in mind, a fact confirmed by conversations between the Commissioner and Dr. Lee.

Dr. Lee stressed to the Commissioner that both he and the late Dr. Katz were technical experts only in the area of natural gas storage. Neither he nor Dr. Katz were safety experts, economists, or legal experts capable of judging the result of a lawsuit against a storage company were gas to escape. The passage in the text has to be read with that, and with the audience to which it was addressed, in mind. The section was designed to alert young engineering students of natural gas technology with little knowledge of risk, or of economics, or of legal matters, to some of the issues which they should be aware of but which are not, strictly speaking, technical engineering issues related to gas storage. Thus the qualifications in the paragraphs entitled "Recommended Policies" as to cost, the use of conditional words such as "if" and "might" and phrasing such as:

> *Acquisition of land in the storage area might be carried out . . .*

and:

> *Ownership of land by the storage operator . . . appears to be a good policy when it does not bear an undue economic burden.*

In light of the public concern over this issue, the commission requested Dr. Rasin Tek, a professor emeritus of the University of Michigan, and a long time colleague of Dr. Katz to prepare a paper for the commission, and to come to Langley and discuss underground natural gas storage, and the views of Dr. Katz thereon, at the commission's technical hearings. Drs. Katz and Tek jointly have written four books, two monographs, and 29 articles in the area of underground natural gas storage.

Dr. Katz was honoured as an "Eminent Chemical Engineer" by the American Institute of Chemical Engineering, while Dr. Tek has been honoured by the American Society of Petroleum Engineers with the title of "Distinguished Engineer". Over the 29 years that they spent as colleagues at the Chemical and Metallurgical Engineering Department of the University of Michigan, the two men supervised doctoral students together, taught subjects together, and consulted to industry together. This involved a large number of gas storage facilities in many states, including Michigan, Wyoming, Illinois, and Indiana. The commission believes that if any person alive is fully familiar with Dr. Katz, his work, and his thinking on the subject of underground natural gas storage, that person should be Dr. Rasin Tek. Similarly, if any person is capable of expanding on the Safety section of the textbook, Dr. Lee, as co-author, should be that person.

The subject of the passage in Dr. Katz' book was the subject of questioning of Dr. Tek by Commission Counsel MacAdams. The full text of the questions and answers are as follows:

[7] Drs. Donald L. Katz and Robert L. Lee, *Natural Gas Engineering: Production and Storage*, McGraw Hill, New York and St. Louis, 1990. The section referred to is reprinted in full in Appendix K.

MR. MacADAMS: Now, we are advised that the late Dr. Katz, in conjunction with Robert L. Lee, have written words which suggest that the surface rights should be purchased. Have you any comment on that, Dr. Tek?

MR. TEK: . . . I remember discussing the matter of storage rights, storage service, and other related economic issues with him in the past on several occasions, where he always would indicate to me that, while the storage rights are the essentials, sometimes it does become necessary to buy out certain farms or certain buildings and appurtenances. Each case, I guess, would have to be judged according to its own merit. But I do not read that one statement in the book as suggesting that one must purchase the house or the basement or the building.

MR. MacADAMS: So this was a subject of discussion between you and the late Dr. Katz?

MR. TEK: Yes, it has been.

MR. MacADAMS: And what criteria did you understand Dr. Katz to be putting forward to determine whether or not surface rights should be bought by the operator?

MR. TEK: Well, quite often the storage operator would like to have a buffer acreage beyond the normally leased perimeter of the storage area. The purpose for that is simply the protection of the ability to further explore, should the gas encroach beyond where the engineers thought it would go in a lateral direction. When such occurrence is indicated by data, observation wells or reservoir studies, one would like to be able to go where the gas appears to be and drill and tie into the system. To make that possible, one must have storage rights. And if there is a certain area that's critical to the operation of the storage field, yet is not on the market, the companies are given under eminent domain, a right to be able to condemn that property and buy it by mutual agreement.

If that is the case —

MR. MacADAMS: Eminent domain is an American legal technique to enable storage companies, amongst others, to take over privately held land rights in order to facilitate the operation of the facility, correct?

MR. TEK: Particular facility, that's correct.

MR. MacADAMS: And did you understand Dr. Katz' advice to be tied in with the United States legal approach of eminent domain?

MR. TEK: Yes.

. . .

MR. MacADAMS: Now, returning to Dr. Katz' view of the utility or advisability of purchasing the surface, did you understand the late Dr. Katz to be of the view that all the surface under which gas was being stored ought, as a matter of prudence to be purchased by the operator?

MR. TEK: Not purchased as land, but storage rights to be purchased or leased.

MR. MacADAMS: And did you understand the late Dr. Katz to be of the view that the land as land, that is to say, the surface use of the land, should be purchased by a prudent operator?

MR. TEK: I only can speculate that what he must have meant would be that where absolutely necessary the land ought to be purchased for, not to disrupt the plans for orderly development of a storage project.[8]

The question of property ownership of surface properties over an underground natural gas storage facility was also

[8] Transcript, pages 1199–1200 and 1201–1202.

canvassed with other technical witnesses, and with company officials at the various facilities visited by the Commissioner.

Other than for the components of the storage facility that are required to be on the surface (well heads, compressor stations, roads, parking lots for vehicles, offices, drying towers, cooling fans, etc.) the conclusion is that the practice is varied. There is no clearly discernable advantage to the residents, or to the company, of any pattern of ownership or land tenure. The only company owning underground natural gas storage facilities that had a policy of ownership of the surface land above was Consumers Gas, which owns the Tecumseh storage facilities near Sarnia. The company owns ten per cent of the land above the storage area, and buys more as it comes on the market. The purpose of these purchases is not related to the safety of residents above the gas storage operation. The purpose is to prevent incompatible industrial use of the land that might endanger the continued operation of the facility by Consumers Gas. The company wishes to maintain the land in agricultural production, and prevent the location of an incompatible industrial plant. In July the Commissioner and the commission's technical advisor visited the Tecumseh field. Mr. Ivan Cuthill of Consumers Gas also testified at the technical hearings. On the subject of ownership, Mr. Cuthill said:[9]

> *With respect to buying the surface, we only are interested in buying the surface if the farmer wishes to sell the surface. You can appreciate that we have a lease with that farmer for the use of the — of his properties to develop underground storage. And with that lease, there is an annual rental that is paid to the farmer.*
>
> *We also rent from the farmer the right-of-way access to a well site, and we pay an annual rental for the actual well site, which after we're finished drilling and setting it up for storage is only a 15-foot square fenced area. And the farmer farms crops right up adjacent to that 15-foot square.*
>
> *Now, if the farmer decides that he wants to sell his farm, we give him the opportunity of selling it to us at the best possible price that he can determine from appraisals. And we do that so that we can be assured that the neighbours that we have within our operating area are in fact the farming community, and that there's no large industrial plant will sit down and locate over top of our storage fields. We prefer it that way.*
>
> *MR. MacADAMS: And why is that?*
>
> *MR. CUTHILL: It's just for reasons of safety, if you will. We have a perfectly safe operation, but we're not so sure about other people, what they may do on top. We're quite happy to be in the — partners with the farming community, but we wouldn't want to see a residential development spring up over top of our storage fields.*
>
> *MR. MacADAMS: Is there some anxiety about the safety of the residents who might live there?*
>
> *MR. CUTHILL: No. It's like an airport. The airport seems to locate itself quietly and carries on its operations, and then before you know it, the developers come in and build residential communities around the airport, and then pretty soon the airport is complaining — or the housing community is complaining about the presence of the airport. It's sort of an analogy that's going through our minds.*

Mr. Guerrini of Gaz de France replied to Mr. MacAdams questions as follows:

[9] Transcript, pages 1285 and 1286.

MR. MacADAMS: Mr. Guerrini, has Gaz de France ever considered, that you know of, buying the surface of lands under which natural gas is stored, in other words, buying up all the farms which are over top of the natural gas site area?

MR. GUERRINI: No sir. We buy just what we need...We don't like (to) have too much land, to buy to much land. We buy well by well.[10]

Mr. Guerrini's testimony is important. Gaz de France is the world leader in the technology of underground natural gas storage in aquifer formations, a fact acknowledged by, among many others, Dr. Katz' co-author, Dr. Robert Lee.

Mr. Vince Grass, the Manager of the Jackson Prairie gas storage project from 1986 to September 1990, answered Mr. MacAdams' questions in the following manner:[11]

MR. MacADAMS: And do the operators of Jackson Prairie have an active policy of purchasing what land becomes available, or is the policy one of, as in Gaz de France, of not becoming landowners?

MR. GRASS: They do not have a policy of purchasing the land. They're not extremely adverse to buying it if somebody offered to sell it.

MR. MacADAMS: What advantages, if any, did you as the hands-on operator of Jackson Prairie find in the company, or the facility owning the land rather than not owning it? Were there any advantages you found?

MR. GRASS: I could see some advantages if you owned all the land, but I don't see it as a necessity at all. There was not interference from the project to the local agricultural commerce and activity. In most cases, the gas storage project and the people working and living on the land got along very well and were able to communicate and support each other in some of their activities.

MR. MacADAMS: And in terms of the ease of operation of the facility, was it advantageous to own the land?

MR. GRASS: I guess it would depend on who else owned it. I think when you own a lot of land, it's additional responsibility, and distraction at times possibly. You could eliminate some potential problems by owning all the land. But at Jackson Prairie that was never a large enough problem to become an aggressive purchaser of the properties.

So it's probable six of one and half a dozen of the other, I think. It could be very advantageous in a place where you had significant distractions, but that was not the situation at Jackson Prairie.

Mr. Griffith commented as follows:[12]

MR. GRIFFITH: No, I would not recommend that they purchase the entire surface. From my experience, this is not necessary. Now, from my experience, we purchase, of course, the compressor lot, where we will have facilities. Possibly, if we have a measurements or regulator station, we would purchase that lot.

We also make arrangements with the landowners where the wells are located, and there is an annual rental payment on that. But beyond that, from my experience, the only lease payments that we have is for the storage reservoir.

[10] Transcript, page 1284.
[11] Transcript, pages 1288 and 1289.
[12] Transcript, page 1198.

> *So I do not recommend, I don't see any reason to buy the entire surface.*

. . .

The issue was also addressed by Mr. Mark Nida of Michigan State. He was asked by Commission Counsel MacAdams whether there was any state policy to encourage or discourage operators from buying surface rights. He replied:

> *No there is not, other than for the compressor station. They'd have to purchase that.*[13]

Mr. Nida was asked whether his state had restrictions regarding placing an underground natural gas storage facility under a populated area. He replied that the South Romeo facility was under such a rural agricultural subdivision, and it went ahead in 1989.[14]

On the question of whether there was any state policy to discourage such proximity of underground natural gas storage and population, Mr. Nida commented that there was not:[15]

> *There are four storage fields that operate with the city limits . . . natural gas is stored underneath them, anywhere from 15,000 to 100,000 people.*

It is clear that the requirements of the natural gas storage operator can be met through a variety of land ownership and tenure arrangements. The views of Dr. Katz and Dr. Lee as outlined in their text appear to the commission to be entirely sensible, as do those of the company which is in the process of acquiring land, Consumers Gas. However those views are not dogmatic requirements; they do not represent the only appropriate avenue to follow in this regard, as a reading of the passage makes clear. It is a distortion of the views of Dr. Katz and Dr. Lee to claim that the text in question is authority for stating that there should be acquisition of surface properties over an underground natural gas storage facility in the Fraser Valley, were one to be established.

The facilities that require surface land are generally on land that has been purchased, but even that is not always the rule. The amount of land for such facilities varies: perhaps 2 to 4 hectares are required for a compressor station, and for the associated equipment, and another 2 to 3 hectares in total area are required in small lots for the wellheads of the injection/withdrawal wells, scattered in 5 metre by 8 metre enclosures, with access roads where needed. If deviated drilling takes place, this area of land is reduced, and the number of wellhead pads is also reduced. At Chemery in France, all injection/withdrawal wellheads are at a single site, in batteries, only a metre apart (Plate 12). The central compressor station is generally at some point over the field, but that is not necessary; with additional piping, it can be moved to any convenient location, wherever it is convenient and causes the least aesthetic impact.

The final aspect of this question is whether there should be populations above an underground natural gas storage facility. Every technical witness familiar with such facilities answered Commission Counsel's question in the same way, namely that population above a natural gas storage facility was a common situation, without any appreciable risk to the residents. Commission field trips confirmed this.

The commission has concluded that the passage in Appendix K on safety from the text of Drs. Katz and Lee provides a sensible and sound introduction to

[13] Transcript, page 1385.
[14] Transcript, page 1382.
[15] Transcript, page 1385.

engineering students and working engineers as to possible risks of underground natural gas storage facilities.

The commission has concluded that human populations above an underground natural gas storage facility, whether urban, rural/residential or rural, are compatible with the existence of the facility, although in some situations where caprock is thin, or faulted, or where inadequate collection zones exist above the caprock, methane detectors in basements, or house construction with no basements at all, would be a useful reassurance and safety provision.

Insurance

During the course of the commission inquiry the issue of whether insurance could be obtained to protect against possible losses or possible groundwater contamination was frequently raised. Specifically, the claim was made at public meetings and subsequently in the media that insurance companies would not insure against hazards arising from the storage of natural gas under a populated area.

The commission examined the issue of insurance through both direct contact with gas storage operators and residents living above such facilities, and through a contract with an independent insurance consultant.

In visits to gas storage facilities in Canada, the United States and Europe, the Commissioner inquired whether the insurability of property posed a problem for gas storage companies, and whether property owners living above underground storage facilities had difficulty obtaining property insurance. None of the individuals spoken to at or near the facilities visited indicated any problems relating to the insurability of property, either from the point of view of the natural gas utility company or from the point of view of landowners.

Copper Roof Management Inc. of Vancouver conducted the insurance investigation. An extensive list of insurance companies, insurance brokers, and other organizations, including Lloyds of London were contacted.

The consultant found that insurance for underground gas storage operators and landowners poses no particular problems. Normal insurance is readily available in existing storage areas, both for operators and for landowners. Moreover, no evidence was found that landowners above a natural gas storage facility were required to pay higher insurance rates than those not above such a facility or that coverage was limited by reason of the existence of an underground natural gas storage facility. The consultant indicated that the main problem in discussing insurance for underground gas storage areas is that many insurers are unaware of the level of risk associated with such a facility. Consequently, many insurers, especially in the general insurance market, are not the appropriate insurers to give an opinion on insurability in this category, by reason of their lack of experience in the area.

The consultant's specific conclusions on the issue of insurance in underground gas storage areas are as follows:

1. *We have concluded that insurance has been available and continues to be available to natural gas storage operators, both for their properties and liability associated with the ownership and operation of underground gas storage facilities. Whether this will soon change or not is hard to predict, but based on loss experience to date, there is no reason to believe that a change is imminent or likely to occur.*

2. *Our general conclusion is that once we step out of the specialized arena and into the general insurance market, particularly personal lines, red flags begin to appear and some insurers become apprehensive. We believe the reason for this incertitude is that underwriters in the general lines sectors perceive the risk to be higher than their more informed counterparts who deal with such risks daily.*

3. *We have concluded there is little reliable evidence to support any claims that property owners are unable to buy insurance in existing storage areas, or that a higher rate is charged than to those not above a gas storage facility. For the most part, insurers are either not aware that some of their insured's are sitting on top of gas reservoirs, or if they are, they don't consider the risk higher than a tornado, earthquake or other natural hazard, which is considered standard and acceptable risk by insurers.*

4. *While it is true that insurance is not available to property owners against the risk of groundwater contamination, such insurance is also not available to the average property or home owner whether there is a gas storage facility or not, nor for that matter, for water contamination from other more likely sources, such as leachate from sanitary landfill, agricultural run-off, pesticides, leaking gasoline storage tanks or defective domestic wells.*

5. *It is possible that if the project proceeds, the publicity surrounding the project may prompt some insurers to decline coverage for properties above the reservoir or storage area. However, in our opinion, once the insurer is presented with a risk profile and understands what the risks are, the problem would be eliminated. The key is the education of the general insurance market by those expert in underwriting and risk assessment of the hazards associated with underground storage, a matter on which there are many decades of experience in other jurisdictions.*

6. *We have concluded there is little evidence to support any allegations made, that insurers would impose restrictions or exclude damage caused by the gas field, beyond existing standard exclusions in a homeowner's or commercial property policy. A more likely scenario is that in the event damage can be directly linked to the operation of the gas field, the insurance company would pay the claimant (assuming the loss was caused by a covered peril, i.e., explosion, fire), and pursue recovery from the operator.*[1]

B.C. Captive Insurance Company

One interesting recommendation of the insurance consultant was that a specific insurance and indemnity plan be developed to protect property owners from any losses not covered by standard insurance policies. Such a plan could be established through a B.C. Captive Insurance Company, which falls under the *B.C. Insurance (Captive Company) Act* (1987) and is regulated by the Ministry of Finance and Corporate Relations. There are currently thirty such companies in the province.

Under such a scheme, a B.C. Captive Insurance Company would be established by the Fraser Valley Gas Project consortium. They would bear the costs of the establishment and operation of the company, and they would also own the funds in the plan. Residents of the Fraser Valley, or citizens from elsewhere in British Columbia, would bear no costs in funding the plan. Citizens affected by any drilling or gas storage accident, or who suffer other losses related to such activities would be beneficiaries.

The main advantage of such a captive is that property owners in the Fraser Valley

[1] Copper Roof Management Inc. "Insurance Research," 1990, pp. 4-5, in the Commission Record.

could be insured against risks such as groundwater contamination and any other form of pollution from petroleum exploration, production or storage, which are not covered by their general insurance policies. The plan would provide a legal guarantee of the assurances of the Fraser Valley Gas Project consortium that they would indemnify or protect any surface property owner who suffers harm. Indeed, the captive insurance company is a very flexible instrument, which could provide the institutional guarantee of many other petroleum industry commitments regarding environmental or economic concerns.

RECOMMENDATION 27

Captive Insurance Company

That if the government allows exploratory drilling to proceed, the Fraser Valley Gas Project establish a B.C. Captive Insurance Company, to be owned and financed by the Fraser Valley Gas Project, to provide insurance coverage for groundwater loss or other environmental damage to surface property owners.

Liability

The commission's review of current tort law indicates that proving causation is a significant hurdle facing plaintiffs in environmental damage cases. This is particularly so in the case of contamination of water wells. A Pennsylvania statute provides a model for more fairly allocating the burden of proof in such cases. There, the operator and/or owner of exploration, drilling, production or gas storage operations is liable for contamination of nearby water sources or supplies unless he or she establishes one of the following:

1. *A survey conducted before operations commenced showed that the pollution existed beforehand.*
2. *The complainant refused to allow a survey before operations commenced.*
3. *The water supply is outside a specified distance of the well, storage area, or other facility.*
4. *The pollution occurred more than six months after operations were discontinued.*
5. *The operator did not cause the pollution.*

RECOMMENDATION 28

Reverse Onus Clause re: Contamination of Water Sources Near Petroleum and Natural Gas Operations

That a reverse onus clause be enacted in the Petroleum and Natural Gas Act or other suitable provincial statute with respect to proving causation in groundwater contamination cases, reallocating the initial onus to the operator and/or owner of the exploration, drilling, production or gas storage operation.

Even where an operator is found liable, tort damages may be difficult to assess, or may simply be an inadequate remedy. Thus, legislation is required to detail the remedial action which must be taken by a polluter to restore an adversely affected water supply. Such legislation could be included in s. 123 of the *Petroleum and Natural Gas Act* or it could form part of an omnibus "Spills Bill" similar to that of Ontario, discussed below. In jurisdictions having this kind of legislation, the duties typically include restoration or replacement of the water supply with

water of adequate quantity and quality, and the provision of plumbing, conveyance, pumping and auxiliary equipment necessary for the affected party to utilize the alternate water supply. Tank trucks and bottled water are acceptable only as temporary water replacement. Finally, the polluter is required to affirmatively demonstrate that the quality of the replacement water is at least equal to the quality of the original water source before it was affected.

Legislation of this type would complement the captive insurance company proposals discussed above by clearly delineating the legal liabilities for water supply damage.

RECOMMENDATION 29

Duty of Polluter to Restore or Replace Adversely Affected Water Supply

That legislation be enacted setting out in detail the remedial action that may be required of persons who are found liable for damaging water supplies.

These adjustments to the tort liability system could be usefully complemented by the implementation of an alternative dispute resolution (ADR) mechanism, by which preliminary attempts would be made to mediate the settlement of a dispute which otherwise gives rise to a tort action. To protect the interests of the plaintiff, the limitation period should run from the date on which the mediator certifies that the dispute cannot be resolved by the ADR process. It would also be desirable to place a time limit within which the mediation process must be either completed or abandoned, e.g., the date on which the limitation period would otherwise have started running, plus six months.

RECOMMENDATION 30

Alternative Dispute Resolution (ADR) Mechanism

That the function of the Mediation and Arbitration Board be expanded to include the mediation of disputes which would otherwise give rise to a tort action.

A more sweeping approach to operator liability is found in the Ontario "Spills Bill" (*Environmental Protection Act*, Part IX), which defines pollutant very widely, requires polluters to notify the government of spills and clean them up, empowers the government to take action if the polluter does not, imposes new civil liability for clean-up costs, broadens recoverable damages, and provides for limited government compensation for some classes of clean-up costs and damages. This "omnibus" form of statutory reform may be especially appropriate in view of the many hazards posed to the environment by industrial activity. Those hazards are not peculiar to petroleum exploration.

RECOMMENDATION 31

Enactment of Ontario-Type "Spills Bill"

That consideration be given to the enactment of legislation similar to the Ontario "Spills Bill". Such legislation could be enacted either as a replacement of ss. 123-25 of the B.C. Petroleum and Natural Gas Act or as a separate Act to deal with sources of pollution generally in the Province.

RECOMMENDATION 32

Creation of Environmental Compensation Board

That if Recommendation 31 is adopted, an Environmental Compensation Board be created, structured and funded in a manner similar to that created by the Ontario "Spills Bill".

The terms of reference of the commission in subparagraph 2 (h) (iii) specifically mention minimum distance and spacing requirements, and instructs that they be reviewed.

For clarity, it is necessary to briefly outline the different purposes served by spacing and minimum distance requirements. Spacing is to control well density, in particular well density over a single underground hydrocarbon pool. The objective of spacing is to avoid unfair exploitation of the pool by some owners, who might otherwise, through the drilling of an excessive number of extraction wells, appropriate to themselves the hydrocarbons that belong to all with subsurface rights. In addition, orderly spacing is very important in maintaining reservoir pressure, and thus maximizing the recovery of petroleum in the pool.

Minimum distance requirements are for a different purpose, namely environmental, aesthetic or safety concerns at the surface. Thus minimum distance requirements prohibit drilling within certain distances of houses, airports, rivers or roads.

Spacing of Wells

With respect to spacing, the commission has examined the requirements in this province and in a number of other jurisdictions whose experience might be of value. In Pennsylvania well spacing units are established *after* hydrocarbons are discovered. The operator of the discovery well, or the owner of affected lands, applies for a well spacing order and a hearing is then held. Any other operator or subsurface rights owner of land in the area concerned may appear and support or oppose the spacing application. The statute then sets out the contents of a spacing order which the department is authorized to make.

The conclusion arrived at after this examination is that there is no clear evidence to support change of the British Columbia requirements. Best Engineering Practice (BEP) is the benchmark that should be used. The existing system provides an adequate spacing requirement and yet allows for adequate flexibility in this regard. No change is recommended, but were change to take place, the Pennsylvania system might provide a model.

Minimum Distances

The situation with respect to minimum distance is somewhat different. The minimum distance requirements in a number of other jurisdictions were considered by the commission. Comparisons from some of these jurisdictions will be found in Appendix J.

It will be noted from this appendix that British Columbia has minimum distances which are generally similar to those of other Canadian jurisdictions and superior to those of the American jurisdictions surveyed. The exception is the drilling distance from water wells in the province of Prince Edward Island. There is no petroleum exploration taking place in that province, and the P.E.I. figure is thus not in current use.

During the hearings of the commission there were a number of calls to have these distances extended. A distance separation from livestock was also suggested. The rationale for such proposals was generally to increase the spacing between the activities of petroleum exploration and the particular structure or activity by reason of safety, or aesthetics. Only rarely was the call for increased spacing coupled with any analysis of the distance required to protect such values, or protect against a

particular risk. Where a reason was given, the population levels of the valley were put forward as rationale.

In the view of the commission, a change in the existing minimum distance requirements should be based on some evidence of the inadequacy of the existing system. No such evidence was provided to the commission at the public meetings or technical hearings, and the commission's independent inquiries in this area have not come up with any substantial reason for major change. Minor, or housekeeping, proposals will be found below.

It is true that increasing the distance will marginally decrease the existing risk, and will also reduce the aesthetic impact of exploratory drilling. However there is no evidence that the advantage gained is significant. The existing systems of minimum distances in North America and Europe, similar to those of British Columbia, have governed the drilling of hundreds of thousands of gas wells. Further, it should be noted that the improvements in drilling technology in the past two or three decades have been significant. Drilling can now be accomplished at (for example) far better noise or safety levels than was the case in the fifties or sixties. The existing minimum distance requirements have not been reduced to account for this improvement. Thus the level of safety and the level of aesthetic protection afforded by these minimum distances are now higher than was the case when they were first introduced.

Does the Fraser Valley population density call for a change to the minimum distance requirements, and should this area be subjected to special regulations in this regard?

The answer to this question becomes clear if the purposes of minimum distance requirements are clearly borne in mind. As stated above, they are for safety and aesthetic reasons. With respect to dwellings, the question then inevitably becomes: Is there some reason that a person living one hundred metres from an active drilling rig in the Fraser Valley should be provided with a higher level of safety and aesthetic protection than a person similarly situated with respect to a drilling rig in the Peace River? It should also be noted that the same minimum distances were in effect in 1986 near Nanaimo when two wells were drilled by BP. Is there any reason that a B.C. citizen on Vancouver Island should have a lower level of safety or aesthetic protection than a citizen of this province who happens to live in the Fraser Valley? Public policy considerations suggest that where risk or aesthetic protection are concerned, where possible all citizens of this province are entitled to be treated alike.

The only exception that comes to mind would be if density of population, and road bottlenecks in the Fraser Valley, led to higher risks by reason of the inability of individuals to evacuate an area as fast as the citizens near the Nanaimo wells, or the citizens near wells in the Peace River. In this case the risk to individuals in different parts of the province is not the same, and extension of the minimum distance should take place up to the point where rough equality of treatment is once more established. This can be done at the present time under existing exceptions to the minimum distance requirements.

The commission thus concludes that the minimum distance requirements have successfully protected the public in the past. Further it concludes that such requirements are providing higher levels of protection to the population at the present time than in the past, and that with further improvements in technology, reduced risk and impact on aesthetic values is likely to continue. Finally it concludes that there are no special considerations in the Fraser Valley suggesting that, as a general rule, there should be any special minimum distance requirements in this area of the province.

The commission recommends the following with respect to minimum

distances and spacing in the Fraser Valley:

RECOMMENDATION 33

Minimum Distance Requirements

That no exception be made to existing minimum distance requirements for Fraser Valley drilling.

RECOMMENDATION 34

Well Spacing

That no exception be made to existing well spacing requirements for Fraser Valley drilling.

RECOMMENDATION 35

Best Engineering Practice

That present flexibility in the Act and Regulation to allow spacing based on Best Engineering Practice (BEP) to substitute for spacing based on horizontal distance be preserved.

The commission does, however, recommend several minor amendments to the current legislation and regulations. This province is one of the few which continues to make a distinction between wells and test holes, the latter being subjected to generally less rigorous minimum distance requirements than wells. While test holes are shallower than wells and do not include holes in which seismic charges may be used, they may pose similar environmental, safety and aesthetic concerns. The commission recommends that this distinction between wells and test holes be abolished.

The *Drilling and Production Regulation* currently provides that a well shall not be drilled within 80 metres of a "permanent building, structure or works". However, a "permanent building" may be nothing more than a storage shed on a remote portion of a farmer's property. Requiring that drilling operations be at least 80 metres from it may be pointless. The commission therefore recommends that this provision be redrafted to provide that the requirement pertain only to buildings occupied by persons or livestock. This would also avoid a situation where a minimal structure is built solely for the purpose of defeating an otherwise acceptable drilling operation.

Similarly, where a surface owner has no objection to operations being conducted within 80 metres of his residence, there seems little reason to enforce this restriction. For example, there may be limited instances where noise abatement is adequate and there is little visual impairment, where the surface owner plans to be absent during a temporary operation, or where the surface owner contracts for additional compensation for increased noise or other inconvenience. The commission recommends, therefore, that the discretionary powers providing that an officer of the division can give written permission for a well to be drilled at a specified position notwithstanding the Regulation, be maintained.

RECOMMENDATION 36

Distinction Between Test Holes and Wells

That the distinction between test holes and wells in the* Petroleum and Natural Gas Act *be abolished.

RECOMMENDATION 37

Drilling Near a Permanent Building, Structure or Works

That the reference that no drilling shall occur within 80 metres of a "permanent building, structure or works" in the Drilling and Production Regulation *be redrafted to provide that the requirement pertain only to buildings occupied by persons or livestock.*

RECOMMENDATION 38

Discretionary Powers of Officers of the Division

That the discretionary powers in ss. 9.01 and 10.01 of the Drilling and Production Regulation, whereby an officer of the division can give written permission for a well to be drilled at a specified position notwithstanding the Regulation, be maintained.

Exclusion Zones

With respect to exclusion zones, the commission has carefully considered all proposals made to it that particular areas of the Fraser Valley be excluded from drilling activity. None have had such special features as to require special exclusion from the present system. The commission notes that minimum spacing requirements now in effect create large exclusion zones of populated neighborhoods in the Fraser Valley. It also notes, and approves of, the flexibility in the current *Petroleum and Natural Gas Act*, which permits variations in the case of special circumstances. Federal legislation in this regard has also been examined. Parks, schools, hospitals, airports, waterways and harbours, GVRD reservoirs and watersheds, roads and residential areas are adequately protected by the present system.

The conclusion is that this flexibility, combined with the current minimum distance restrictions, allows for appropriate restrictions on drilling to protect both the resident population and any special values that might exist in a particular case. The commission does not believe that blanket exclusion zones are desirable or are warranted at the present time.

General Considerations

Petroleum exploration involves many highly complex technological procedures. Thus, the *Drilling and Production Regulation* (and other regulations addressing the technological aspects of petroleum exploration) must retain a certain flexibility, so that operators are not inadvertently prohibited from using the most current procedures available. Further, operators must be left sufficient flexibility to respond appropriately to the many different situations which might arise in the course of their activities. The following recommendations address these concerns.

Government policy must be clearly stated. The specific safety concerns, environmental hazards or other issues addressed by a regulation should be clearly set out in the regulation itself. Government draftspersons are thereby able to avoid the onerous task of prescribing highly detailed regulations, attempting to anticipate every possible eventuality in a highly complex industrial process. Further, highly specific regulations would have to be reviewed and updated frequently, perhaps on an ongoing basis, to ensure that they reflect current technological advances. Finally, where regulations are flexible and goal-oriented, the defence of statutory authority in tort actions is less likely to be successful.

RECOMMENDATION 39

Statement of Purpose in Each Division of Drilling and Production Regulation

That each Division of the Drilling and Production Regulation *commence, where applicable, with a statement of the purpose or goal of that Division.*

RECOMMENDATION 40

Regulations Not to be Highly Specific

That in prescribing specific equipment, procedures and other technological requirements in a regulation, sufficient flexibility be maintained to ensure that the most advanced procedures, or procedures most appropriate for particular circumstances, can be used by the operator.

RECOMMENDATION 41

Regular Review of Regulations if Highly Specific

That if the Recommendation above is not followed, regulations be reviewed regularly, perhaps on an ongoing basis, to ensure that they reflect current advances in drilling technology.

The following Recommendation would be especially important if Recommendation 40 above were not adopted.

RECOMMENDATION 42

Preserving Division's Discretion to Set More Stringent Standard than Regulations Provide

That the discretion of the Minister, division head and officers of the division to set procedures and fix standards of equipment, notwithstanding the regulations, be preserved.

Drilling Deposits and Performance Bonds

The commission examined the deposit and bond provisions of various Canadian and American jurisdictions, and found a wide variation in both monetary amounts and financial structure requirements. The commission has considered the relative merits of such options as increased deposits, elimination of specified maxima, alternative forms of security such as surety bonds and bank letters of credit, and the use of performance bonds in addition to or in lieu of drilling deposits. The following recommendation is made as best providing the most flexible administrative vehicle for making available the features of all these alternatives.

RECOMMENDATION 43

Forms of Security to be Provided by Operators

That Part (21) of the* Drilling and Production Regulation *be amended, to give the Minister the discretion to determine the amount and type of security to be provided.

The Regulation might further provide that in fixing the amount and type of security, the Minister shall have regard to the nature, complexity and extent of the drilling operation and the estimated cost of any potential remedial action that is reasonably foreseeable when the permit is issued.

The *Petroleum and Natural Gas Act*, ss. 122-35, currently provides that the Minister may deal with wild wells and cases of spillage, applying the drilling deposit to expenses so incurred. The commission recommends that this be extended along the lines of the Alberta and Ontario legislation, extending the Minister's power to take over non-complying wells which are not necessarily an imminent hazard or causing or about to cause spillage, but where there are violations not remedied after notice. These sections would also allow forfeiture of the drilling deposit to cover expenses incurred by the Minister in such actions. For example, the following sections may be added to the *Petroleum and Natural Gas Act*, Part 12, Division (8):

125.1 (1) Where the minister is of the opinion that any operation in respect of a well has been discontinued or delayed for an unreasonable period of time, he may notify the operator by registered mail that the well is to be plugged within 30 days after the notice is sent.

(2) If within 30 days after the notice is sent the well is not plugged or the operator fails to satisfy the minister that there is good reason for failing to plug the well, the minister may take possession of the well.

(3) Where the minister takes possession of a well under subsection (2), he may plug the well and sell any salvage therefrom or he may sell the well.

(4) The minister may recover from the operator of the well,

(a) the expenses incurred in plugging the well, where there is no sale or salvage; or

(b) the excess of the expenses over the net proceeds of the sale, where there is a sale.

125.2 (1) Where a well or any part of a well is not in compliance with the Act, the regulations or any order, the minister may notify the operator by registered mail of the non-compliance and may set a

date by which the non-compliance is to be corrected.

(2) Where the non-compliance is not corrected by the date specified in the notice, the minister may take possession of the well and may,

(a) cause such things to be done as are necessary to make the well conform to the Act, the regulations or an order; and

(b) remove and sell the well.

(3) The minister may recover from the operator of the well,

(a) the expenses incurred in any action taken under subsection (2), where there is no sale; or

(b) the excess of the expenses over the net proceeds of the sale, where there is a sale.

125.3 (1) Where the minister takes possession of a well under section 125.1 or 125.2, there is forfeited and shall be paid to the Minister of Finance such sum as the minister determines out of the total security deposited by the operator, or in respect of any performance bond posted by the operator, or both.

(2) In sections 125.1, 125.2 and this section, well includes a test hole.

RECOMMENDATION 44

Extension of Minister's Power to Take Over Non-Complying Wells

That the Minister be empowered to take over non-complying wells which are not necessarily an imminent hazard, but where there are violations not remedied after notice. The powers would include: plugging the well or taking action necessary to bring it into compliance, and sale of salvage or of the well itself to cover expenses incurred by the Ministry. The amendment would also provide for forfeiture of any deposit or bond, to cover expenses, as well as a cause of action for any deficiency not covered by the Minister's other remedies.

Monetary Fines and Related Mechanisms

There is a need to harmonize the fines authorized by the *Petroleum and Natural Gas Act* with fines under other provincial statutes dealing with damage to the environment. The fine for all offences under the Act is currently $500 to $5,000 per day, whereas the possible fine for some other environmental offences is now $1 million, and in the case of intentional environmental damage, $3 million.

The commission has considered a number of possible fine reform options, including: raising statutory maximum fines that are exceptionally low; raising maximum fines generally; establishing minimum fines; raising maximum and minimum fines for corporations; and imposing minimum fines or higher maximum fines under specified special circumstances. A higher maximum fine under section 142 of the *Petroleum and Natural Gas Act* would afford the courts maximum flexibility in dispensing an appropriate fine for aggravated offences, while preserving their discretion to show leniency where an offence is not particularly serious. It would also permit incorporation of the concept of fines equivalent to benefits found in section 34.1 of the *Waste Management Act*. The following recommendations appear to be the most suitable for this province:

RECOMMENDATION 45

Raising Maximum Fines Generally

That s. 142 of the **Petroleum and Natural Gas Act** ***be amended to provide for a higher maximum fine than that currently available, for any offence under the Act or Regulation.***

RECOMMENDATION 46

Minimum Fine

That the minimum fine should be left at its current level of $500.

RECOMMENDATION 47

No Distinction Between Maximum Fines for Corporations and Individuals

That a relatively high maximum fine be set for both individuals and corporations, thus maximizing the discretion of the courts to set fines appropriate to all the circumstances of a particular case.

Forfeiture provisions might be useful where a corporate defendant is a shell company with no assets, uses only rented equipment, ignores orders or fails to pay fines. Because corporations cannot be imprisoned, forfeiture may provide a drastic penalty for use in the limited circumstances of intransigent offenders. Forfeiture provisions might also be useful in the case of non-corporate defendants.

Similarly, consideration should be given to cancellation or suspension of permits, licences and leases as a sentencing option. Such a sentencing power would parallel similar powers currently granted to administrators under ss. 35, 99, 104, 107 and 108 of the *Petroleum and Natural Gas Act*.

RECOMMENDATION 48

Forfeiture

That s. 142 of the* Petroleum and Natural Gas Act *be amended to provide forfeiture provisions as a sentencing option. Such a provision might follow the form of the draft statute in Recommendation 44.

RECOMMENDATION 49

Suspension or Cancellation of Permits, Licences and Leases

That s. 142 of the* Petroleum and Natural Gas Act *be amended to confer upon the courts the option in sentencing of cancelling or suspending a permit, licence or lease where there has been a violation of the Act or Regulation.

S. 142(3) of the *Petroleum and Natural Gas Act* currently provides that where a corporation is convicted of an offence, an officer, director or agent of the corporation who authorized, permitted or acquiesced in the offence also commits an offence and is liable to punishment under s. 142(1) of the Act (the general punishment section). Under s. 142(1), a human agent actually committing a violation of the Act or the Regulation also commits an offence. At present, the Act provides for fines but not incarceration. By contrast, the *Waste Management Act* provides for three years imprisonment where a person intentionally causes damage to or loss of the environment.

The possibility of imprisonment may be useful in this context. For example, a serious offence may be committed by a foreign national who could avoid sanctions by leaving the province. Incarceration may also be appropriate for the rational, calculating offender.

RECOMMENDATION 50

Imprisonment of Corporate Officers and Employees

***That s. 142(1) of the* Petroleum and Natural Gas Act *be amended to bring it into conformity with the* Waste Man-

agement Act, ***particularly subsection 16 of section 34, to provide for terms of imprisonment in lieu of or in addition to any fine levied.***

It has been suggested that regulators who can impose administrative penalties are in a better position to ensure compliance than administrators who must resort to criminal prosecution. The rationale is that the administrative process responds to risk rather than to harm, does not unduly stigmatize offenders who are thought not to warrant moral opprobrium, entails minimal operating costs, and imposes monetary penalties large enough to have a reasonable prospect of deterring offenders.

There are also cases where criminal sanctions are appropriate, so that the most effective mechanism might be a combination of administrative penalties for routine offenders and criminal sanctions for the worst offenders.

In Pennsylvania, the Environmental Hearing Board is empowered to impose a civil penalty of up to $25,000 plus $1,000 for each day of continued violation for any violation of the state's oil and gas statutes or regulations. This civil penalty may be imposed in addition to other penalties.

RECOMMENDATION 51

Administrative Penalties

That administrators of the **Petroleum and Natural Gas Act** ***be empowered to impose administrative penalties for breaches of the Act or Regulation, possibly modelled on the practice of the Workers' Compensation Board or on the legislation of Pennsylvania.***

Enforcement Powers

The word "order" is not used consistently throughout the *Drilling and Production Regulation*. In several sections, an officer of the division is authorized only to "request" but such a request is not currently enforceable. To ensure compliance with regulations, an amendment of s. 107.02 is required.

RECOMMENDATION 52

Clarification of Enforcement Power Under *Drilling and Production Regulation*

That s. 107.02 of the **Drilling and Production Regulation** ***be amended to read: "Where an officer of the division is authorized to issue an order or make a request under these regulations, the person to whom the order is issued or request made shall comply with the order or request."***

Local Control and Veto

During the public meetings, and indeed throughout the life of the commission, the issue of whether Fraser Valley residents should be required to bear risks of developments that benefit others elsewhere was raised by opponents of the Fraser Valley Gas Project. The point was made in a variety of ways, but in essence the argument was that as the exploratory drilling, and any possible production or underground natural gas storage, would take place in the Fraser Valley, local residents who may be impacted by such developments or who may bear increased risk as a result of the activity should have the right of determining whether they should proceed. In essence, the proponents of this view were asking for a local veto of any project in their area or neighborhood, which was variously described as the whole Fraser Valley, a township, or any portion of it that might be affected. This latter view would require virtually unanimous approval by those residing near a proposed energy facility.

The issue is not unique to the Fraser Valley or to the petroleum industry. The question of who bears risk and who benefits from the risks taken is an important ethical aspect of many environmental, industrial, transportation and energy developments.[1] Where to locate hazardous waste facilities, halfway houses for former prison inmates, or energy facilities are all difficult questions involving benefits to society as a whole, but also varying degrees of risk to people in the vicinity of the facilities. The issue has created an extensive interdisciplinary literature.[2]

With respect to the Fraser Valley, there are some important considerations. First is the fact that few areas of the Fraser Valley are without domestic gas supplied by B.C. Gas, or electricity supplied by B.C. Hydro. At the present time the residents and industry of Greater Vancouver and the residents and industry of the Fraser Valley are thus in the same position regarding the benefits of the electrical and natural gas energy systems of this province. Both receive benefits, the costs and risks of development and exploitation of which are borne primarily by residents of the Peace River area, or of the Kootenays.

Second, given the extensive transportation links in the valley, of rail, road, river and air, and the numbers who travel to work in the urban areas of Vancouver, or whose work exists because of the proximity of the urban area, the concept of distinct Fraser Valley and Vancouver communities for the purposes of energy system risk and benefit is hard to sustain. Perhaps the Lower Mainland can be considered as a single community or unit, separate from other areas of the province; on this no opinion is offered. However to separate out the Fraser Valley and the metropolitan areas of Vancouver for the purposes of risk raises immediate problems. The people of the port of Vancouver take risks in transshipping goods destined for the Fraser Valley. Similarly, the residents of the Fraser Valley incur risks from the shipment of goods by rail destined for the Greater Vancouver metropolitan area. Many farmers of the Fraser Valley have had their properties affected, even cut in two, for highway links; these serve other Fraser Valley residents just as much as the resident of the metropolitan area, and

[1] The commission wishes to acknowledge and thank Dr. Edward Keyserlingk of the Center for Legal and Medical Ethics of McGill University for his helpful comments on some of the ethical issues involved.

[2] For some recent examples, see O'Hare, Bacow and Sanderson, *Facility Siting and Public Opposition*, Van Nostrand Reinhold, New York, 1983; O'Hare, M, "Not on My Block You Don't — Facility Siting and the Strategic Importance of Compensation", *Public Policy*, 25, pp. 207-258; Susskind, L. *Breaking the Impasse*, Harvard University Press, Boston, 1989.

both users create risks to those who live alongside the highways.

It should be noted further that the proximity of Greater Vancouver creates benefits for Fraser Valley residents which others elsewhere in the province do not share, or share in a very different way. For example, property prices in the Fraser Valley are substantially higher than they would be if the area were more distant from the metropolitan area; let us say at Grand Forks, Clinton, or Chetwyn. Greater Vancouver cultural facilities are also easily accessible to Fraser Valley residents. This is not so for the smaller communities of the Peace River, or of Omineca, or of the Charlottes. The Fraser Valley resident also enjoys the benefits of easily accessible specialized medical facilities, something the resident of the Kootenays or of the Cariboo, or of the Peace River, must spend time and money travelling to obtain. This, of course, works both ways, and it should also be pointed out that there are also costs to this proximity to a major urban center. The regrettably poor air quality of Chilliwack is not the result of car and other emissions in that city alone, but the result of car and other emissions of all other communities in the Fraser Valley to the west, including Greater Vancouver. The Fraser Valley and Greater Vancouver are not, for major services such as energy and transportation, separate communities, but instead interdependent parts of the single Lower Mainland unit.

Third, to adopt the principle of local control and veto would fly in the face of accepted concepts of the provincial or national community, adopted and in practice for many decades. For example, two and three decades ago the properties of many Kootenay and Peace River residents were expropriated for dam construction and for the reservoir areas required. Other residents of these areas, living downstream, were (and still are) subject to the risks of dam failure. The benefits of this expropriation accrue to all British Columbians, including the half of the population that lives in the Lower Mainland, half a million of whom are residents of the Fraser Valley. To suggest that the residents of the Fraser Valley (always assuming it is possible to determine with precision their collective view) have the right of veto over energy developments within their area, but that the residents of the Peace, or of the Kootenays do not, is to suggest that the residents of one part of the province have more rights than those of another part of the province, a position that flies in the face of accepted standards of equality and fairness.

The argument that the local Fraser Valley community should have veto power and thus the control of energy facility developments within the valley cannot be sustained. The issues involved are appropriate for provincial decision making, not for local or regional control and veto.

Compensation

While local control or veto is inappropriate, compensation to the population of a local area for risk, inconvenience, or aesthetic effects is not. Again, there is a well established literature in this area, which need not be reviewed here, which describes in some detail how benefits to the general community can be provided in order to compensate for the impact or risks associated with petroleum industry operations.

In the case of an energy facility in the Fraser Valley, such compensation would principally take the form of municipal tax revenue for the municipal or regional authorities. In some parts of Alberta, for example, the petroleum industry provides 85% of local tax revenues. Thus local residents benefit directly by way of a very low tax load for high levels of services, and this in part or in whole compensates for possible increased risk, inconvenience and adverse aesthetic effects resulting from the operations of the industry.

In addition to local tax revenues, some of those impacted by petroleum industry developments, particularly farmers or landowners, receive direct compensation for inconvenience or loss. The practice of the industry in this regard in the Peace River area and Alberta provides a guide. These are essentially private arrangements; however the services of the Petroleum Mediation Board of British Columbia is available in cases of dispute.

It is important to note that while the compensation issue is appropriate for public discussion and negotiation, it is virtually impossible to enter into such activities until a decision has been reached to proceed with a project. In the case of the Fraser Valley Gas Project proposal, for example, those opposed to the exploratory drilling made it clear that they had no wish to discuss compensation issues. As their position was hostile to any drilling whatsoever, they correctly felt that discussing compensation could only weaken their case. Thus only if a decision is made to proceed with exploratory drilling should the matter of possible compensation be discussed further. Negotiation and discussion of compensations previous to such a decision cannot be expected to be meaningful. Those who oppose the project inevitably feel that such discussions compromise their basic position. They therefore rarely take part. If they do take part, the discussions inevitably get sidetracked onto the issues which are felt to be more fundamental, namely the go/no go issues. Discussing these issues, however, destroys the basis of the negotiations on compensation.

Finally it should be noted that in negotiation and compensation, trust between the parties is the critical factor for success. Trust in turn depends on minimizing the areas of potential conflict. A wide open debate on all aspects of a proposal, including whether it should proceed or not, such as took place before this commission was established, and during its existence, is virtually a guarantee of a lack of trust between the parties. This lack of trust was noted by the commission in May, at the outset of its activities. Regrettably, but not surprisingly, a sense of trust between the Fraser Valley Project consortium and its critics could not later be developed.[3]

The experience of Alberta on the Caroline development is a case in point.[4] This is a gas development of close to a billion dollars in a densely populated rural area of small holdings, adjacent to Calgary, involving 35% hydrogen sulphide gas. There were two competing proposals of two different companies, Shell and Husky; Shell won Energy Resources Conservation Board approval. Here the discussion and negotiation with the public has been extensive over the past three years, and many elaborate and highly expensive compensatory provisions have been agreed to by the companies in their efforts to line up public support and approval. These include noise aspects, land values, air and water pollution issues and even include traffic patterns for trucks. However it is not, at this stage at least, a model that can be used in the Fraser Valley, as here the question of whether the Fraser Valley Gas Project will get approval to proceed is still entirely unknown.

Communication

Another factor that has prevented meaningful discussion between the Fraser Valley Gas Project consortium and the opponents of its proposals was the lack of effective communication of the risks involved when the proposals were first made public. Interest groups traditionally resist all attempts at negotiation and

[3] For a discussion of the importance of trust in such negotiations, see O'Hare et al. *Facility Siting*, 1983.

[4] The Caroline project was described for the commission by Messrs. Morin and Nichol of the Alberta Energy Resources Conservation Board at pages 884 ff. of the Transcript. The socio-economic impact assessment of the project was also presented.

compensation until the low level of risk of a particular facility or proposal is fully understood. Once organizations develop whose memberships have been recruited on the basis of an exaggerated perception (from the technical point of view) of the risk, and on a technically unjustified high level of fear, it is, as this commission has experienced, very difficult to return the discussion to realistic levels.

This problem is not unique to the Fraser Valley, or to the Fraser Valley Gas Project proposal. It is a well recognized phenomenon, which has developed its own specialization, particularly over the past decade. Risk communication is now a specialty in its own right, with an extensive literature. Of particular interest are *Risk Communication: A Guide for Plant Managers*, 1987, of the Chemical Manufacturers Association; *Risk Assessment in the Federal Government: Managing the Process*, 1983, National Academy Press, Washington, D.C.; and *Improving Risk Communication*, 1989, National Academy Press, Washington D.C. The latter two documents are publications of the United States National Research Council.

If the government decides that exploratory drilling should not proceed, communication of the risks involved and subsequent negotiation becomes unnecessary. Similarly there is no need to discuss compensation to those affected by drilling, as no drilling will take place.[5]

However, if the government decides that exploratory drilling should proceed, effective communication of the risks involved is very important, as are subsequent negotiations and compensation discussions with those who have concerns over the impact of such exploratory drilling.

RECOMMENDATION 53

Communications Program

That in the event the government permits exploratory drilling, an effective communications program of the levels of risk that are posed by the drilling should take place.

RECOMMENDATION 54

Negotiation and Compensation

That in the event the government permits exploratory drilling, negotiation and compensation discussions with those who may be affected by the drilling should be undertaken.

RECOMMENDATION 55

Citizens Advisory Council

That in the event the government permits exploratory drilling, a Citizens Advisory Council be set up to provide advice on aesthetic and amenity issues related to the drilling.

Intergenerational Issues

During the public meetings the issue was raised whether it was appropriate for this generation to be increasing its consumption of natural gas so quickly, with the obvious result that subsequent generations will have less to use.

The issue has two aspects: first, the use of natural gas as a fuel, and second, whether some succeeding generation will have better uses for natural gas than burning it up.

[5] The compensation required for those whose property rights and expected future revenues are affected by such a decision is discussed in Chapter 14.

The second issue will be dealt with first. The commission has puzzled over this matter without coming to any satisfactory conclusion. The upshot of its thoughts on the matter is that as there is no way of determining whether an alternative fuel to gas may also have a better use in the future, the problem is essentially insoluble. Regardless of which fuel is chosen to be used at the present, in the future the fuel chosen may have greater value than its competitors today. The commission has no doubt that future generations in the first years of the third millennium will regret certain fuel choices of the generation of the latter years of the second millennium. No doubt those generations will be facing difficulties of their own of a similar nature for the generations yet beyond them, and thus will be understanding of our dilemma in this regard today.

Consideration of the first question has had a more conclusive result. There is little doubt that future generations would find natural gas as a very attractive fuel, just as we do today. There is also no doubt that existing known reserves have a finite life, calculated by the Times Guide to the Environment[6] as somewhere between forty and fifty-six years. Thus, despite new finds and other increases in reserves, the possibility of natural gas becoming a fuel of the past is real.

However, if the present generation does not undertake some fuel substitution to lower carbon dioxide fuel emissions, the strong possibility also exists that global warming, desertification, the melting of icecaps and other such undesirable developments will give future generations far more to worry about than if this generation makes the effort to switch to a fuel with low carbon dioxide residues. For B.C. at this time, natural gas is such a fuel.

Further, the other fuels that might be used by this generation which create greater environmental impact than gas may not do so in the future. Given the advance of technology, it can be expected that future generations will be much better able to burn coal with less damaging emissions than we are able to do today. Further, the problems currently associated with nuclear power may be, in part at least, overcome. Thus it appears unwise for this generation in British Columbia not to switch to the presently less polluting fuel, of which we have been endowed with more than our share, and to leave to future generations the task, which they undoubtedly will handle better than we can, of using other fuels.

A further consideration, directly relevant to the issue of Fraser Valley exploration, is that exploration is easier where there are not high densities of human populations. This is not because of risk, or of technological difficulties; the risk from construction in front of the Pan Pacific hotel is greater, if one can trust Workers Compensation rates, than exploratory drilling of natural gas wells. Drilling in populated areas can be done, and is being done in cities in many parts of the world,[7] and given trends throughout the world, one day may well be done in urban settings here.

However it is easier and cheaper to drill where populations are not present in high densities, and this is unlikely to be different in the future. Thus not to drill at the time when population densities are less shifts higher costs onto future generations.

[6] *The Times Guide to the Environment: A Comprehensive Handbook to Green Issues*, The Times Books, London, 1990, page 100.

[7] According to Dr. Tek, drilling took place directly under the Arc de Triomphe in Paris last year, Transcript, p. 1249.

Procedures Adopted to Ensure Public Participation

From the outset of this inquiry, a major objective of the commission was to ensure the highest practical level of public participation. To this end, approximately a week after his appointment, the Commissioner met with representatives of the Friends of the Fraser Valley to obtain their views on the terms of reference and how the commission should proceed. In the afternoon following that meeting the Commissioner had his first meeting with the companies proposing the drilling program, the Fraser Valley Gas Project group.

The procedure adopted was to have an initial meeting to allow the companies to outline to the public what their proposals consisted of, and to follow that initial meeting with public meetings in various Fraser Valley communities to allow the concerns of residents to be raised and become known to the commission. The initial meeting took place at Aldergrove Community Centre on 12 June 1990, and the nine public meetings took place in the subsequent month. There was no evaluation at the public meetings of the validity of the concerns expressed, nor did the commission permit the consortium to reply to their critics. The objective was to allow the public to speak up without fear of questioning either by experts of by lawyers. The schedule of public meetings is found in Appendix D.

In addition to the formal public meetings, the Commissioner met with most of the mayors of the municipalities of the area and their councils. Meetings with other groups, such as farm organizations, took place when requested. Also, the public was invited to drop in to the office or arrange a meeting at the office with the Commissioner and commission staff. Many took advantage of this opportunity for face to face discussion.

Following the public meetings, the commission analyzed the concerns presented, and initiated inquiries with people knowledgeable in the various areas of concern. In most cases where opinion evidence appeared to be useful, the commission arranged witnesses for the subsequent[1] technical hearings. A schedule of the witnesses who appeared at the technical hearings, and the subjects they covered is found in Appendix E. The transcript of these hearings runs to approximately 1500 pages, and 57 documents were introduced as exhibits. On some issues witnesses were not called, and instead consultants' papers were commissioned, or direct investigations carried out, as appeared appropriate.

During the period from the end of the public meetings to the beginning of the technical hearings the Commissioner and the commission's technical advisor visited various drilling sites or gas storage operations. A list of the visits made is found in Appendix G. In addition this period was utilized for preparatory sessions with witnesses, at which time representatives of the Fraser Valley Gas Project consortium and of the Friends of the Fraser Valley were invited to suggest the names of potential witnesses, to propose lines of questioning and individual questions to be put to the witnesses, and to take part in the pre-session organization of the technical hearings. The Chair of the Friends of the Fraser Valley, for example, by letter dated 8 August 1990 suggested five witness. All were invited. Four gave evidence, while the fifth, Dr. Gary Rogers of the Pacific

[1] Technical Hearings took place 27 August 1990 to 6 September 1990.

Geoscience Centre, asked to be excused by reason of the appearance of another witness from his office, Dr. Dieter Weichert.

At the technical hearings, the process of public participation was continued by way of inviting representatives of the consortium and the Friends to sit adjacent to commission counsel (the only person other than the Commissioner authorized by the rules adopted in July to question witnesses) and consult with him on questions that they felt should be asked or lines of questions that should be pursued. Indeed, even members of the public who attended the hearings took advantage of the opportunity to get together with commission counsel and propose questions that they wished to be put to witnesses.[2] In addition, between the sessions, Commission Counsel Douglas MacAdams was available for discussion and suggestions as to how questioning should proceed and what questions should be asked.

Following the technical hearings, the transcript of the hearings was made available to the public at the commission's Langley office, and an opportunity was given for any interested member of the public to correct or dispute any statement of fact that might have been made. The Commissioner also expressed his willingness to reopen the technical hearings to deal with matters not covered.[3] No representations were made in this regard. Finally, the opportunity was given for any person to provide the Commissioner with a summation statement in which he or she could outline what conclusions the Commissioner should come to from the evidence presented. It should be added that because of the delays to the commission time table that took place by reason of the investigation into allegations by the Friends of the Fraser Valley of impropriety by the proponent companies and of perjury by civil servants who testified, the deadlines for presenting both the correction statements and the summation statements as outlined on 6 September 1990[4] were extended into November.

The paragraphs above describe the process followed by the commission, particularly the process to obtain a high level of public involvement. The results and success of the process deserve analysis.

Withdrawal of Drilling Opponents

On 4 September 1990, at the 13th of the 16 technical hearings, a spokesperson for the Friends of the Fraser Valley announced that the organization was withdrawing from further participation in the commission process. In addition, certain allegations were made which were the subject of the Commissioner's special report to the Lieutenant Governor in Council of November 1990, and which need not be commented on further at this point.

The timing of this was unexpected; on the 23rd of August a letter from a director of the Friends of the Fraser Valley to the local press[5] had recommended that the public attend the technical sessions. Further, only a day or two before, another spokesperson had provided the commission with what he described as the group's technical paper, with the request that he be telephoned if there were any questions about it. The decision to take no further part in the commission process appeared to be a deliberate change of policy by the group.

While the timing was unexpected, the fact that the group withdrew was not. The process adopted by the commission had been thorough, and the opportunity to take part had been extensive. For those determined to have the commission report negatively there was clearly a problem; a

[2] See, for example, Transcript, page 1301.
[3] Transcript, page 1450.
[4] Transcript, page 1449.
[5] Aldergrove Star, 23 August 1990.

fair and open process, with full public involvement, inevitably causes those who take part to share in some degree with the responsibility for the conclusions arrived at. Having heard three-quarters of the technical witnesses, including some of the witnesses that they had asked for, the group no doubt recognized that the evidence was not overwhelmingly adverse to exploratory drilling, and thus the ultimate commission report might not be in line with their predetermined views. Further participation in a fair and open process would thus inevitably weaken their position once the commission reported. Thus, ironically, the more successful the process had been in being open and accommodating to public participation, the less likely there was of a group such as Friends of the Fraser Valley continuing with the process until the conclusion — unless of course, the group was willing to alienate its partisan supporters, forego the predetermined position, and accept that conclusions in the report should be based on technical analysis. This was obviously unlikely.

The comments above deal with the specific example of the Friends of the Fraser Valley before this commission. What took place, however, is a well known phenomenon which has regularly occurred elsewhere in similar situations. It stems from a fundamental difference in approach between such special interest groups and what may loosely be called "expert opinion."

Technologically sophisticated persons, or "experts", employ risk assessment techniques to evaluate hazards. Generally this takes the form of statistical probability of harm. Such techniques are well established and well proven. By contrast, when considering hazards, most citizens rely on intuitive judgments. Their perceptions are formed by the news media, which conveys a daily stream of information on mishaps and threats occurring throughout the world, and inevitably does not cover the routine successes, which are not news items.

During the past decade, researchers in the field of public perception of risk have examined why some technologies are feared and others are not. It has been important work; billions of dollars, not to mention large numbers of human lives, are affected. They have attempted to determine what factors underlie public perceptions of something being "risky", and why this sometimes varies so dramatically from what risk analysts have established as realistic. Decisions on whether to respond to the public's perception of risk, or the views of the experts, have critical political and social consequences. British Columbia has many examples of such dramatically opposing views on risk; over the past decade the professional view of cancer researchers on the risks of cancer from PCBs, for example, has been quite different from the public's perception. Dealing with the issue is a multi million dollar matter, which could conceivably affect many lives.

It is not possible in this report to discuss the subject in the detail it deserves, although more will be written below under the heading of "Reaction to the Commission's Report." The work of P. Slovic, particularly his article "Perception of Risk" in *Science*, Vol. 236, at pages 280 to 285, and on which the paragraphs above lean heavily, should be consulted if further theoretical analysis is of interest.

Thus the participation of the public in the preparation of this report has been extensive. That one segment of the public with a preconceived view as to what the outcome should be chose to take part for only a portion of the process is regretted but is not surprising.

Public Hearings and Funding Citizen Intervenors

As noted, the commission regards public participation as an important element of an inquiry process such as this. The variety of views and opinions result in better decision-making, as well as

allowing both industry representatives and concerned third parties to publicly present their concerns. The recommendations below are based on this experience, and on what is perceived to be a weakness in the current British Columbia provisions for public participation.

Hearings are expressly excluded where the Minister of Environment or the Lieutenant Governor in Council is considering the issuance of an environmental protection order. Where circumstances do not require an immediate decision, the commission is of the opinion that the possibility of a hearing should not be precluded.

RECOMMENDATION 56

Expanded Use of Hearings

That hearings be held during the process of approval of petroleum exploration proposals.

RECOMMENDATION 57

Provision for Hearing Where Environmental Protection Order Under Consideration

That the Environment Management Act, *ss. 4(3) and 4(5), be amended to provide for a hearing where the Minister of Environment or the Lieutenant Governor in Council is considering the issuance of an environmental protection order in respect of any existing or proposed petroleum and natural gas operation.*

Where hearings are held, the Ontario *Intervenor Funding Project Act, 1988* provides a model for intervenor funding, particularly useful where relatively impecunious intervenors represent a significant public interest that would not otherwise be adequately represented.

The Ontario scheme applies to hearings under that province's *Environmental Protection Act* and *Ontario Water Resources Act*. Intervenor funding may only be awarded in relation to issues which affect a significant segment of the public and which affect the public interest and not just private interests. In deciding whether to award funding, the funding panel considers the following factors: the intervenor represents a clearly ascertainable interest; the representation would contribute substantially to the hearing; the intervenor has inadequate funds; the intervenor has made reasonable efforts to raise funding elsewhere; the intervenor has established a record of interest in and commitment to the subject matter; the intervenor has a clear proposal for use of funds; and the intervenor has appropriate financial controls.

RECOMMENDATION 58

Intervenor Funding System

That where hearings are held, public input be facilitated through implementation of an intervenor funding program similar to the Ontario Intervenor Funding Project Act, 1988.

Citizen Input — Conference Process

When a private individual comes into possession of information indicating a statutory or regulatory violation by an operator, his remedy is currently limited to filing a complaint with EMPR. The commission is of the opinion that there is value in formalizing a process by which the complainant, especially if potentially directly affected by an adverse outcome

flowing from the violation, could become involved in seeking compliance.

Illinois legislation allows a concerned citizen the right to request informal conferences on pending mine permit applications, or to request that the state conduct an inspection. The system does not appear to be abused by overuse; in 1989 one informal conference was held and two public hearings were conducted as a result of citizens' requests.[6]

A Pennsylvania statute suggests a model for a negotiated compliance process by which interested parties can initiate such action. These conferences are limited to seeking enforcement orders for violations of the statute and do not include provisions for an award of damages. This allows private citizens affected by non-complying operations to seek to enforce, at low cost, statutory and regulatory provisions. The role of the British Columbia Petroleum Mediation and Arbitration Board could usefully be expanded to administer this activity.

RECOMMENDATION 59

Private Citizen Conference Process to Negotiate Compliance with Statute and/or Regulations

That the Petroleum and Natural Gas Act *be amended to provide for a conference process whereby private individuals affected by non-complying operations may seek a conference with Ministry officials and industry representatives, in an effort to negotiate compliance with the Act and regulations.*

Expected Reaction to the Commission's Report

It should be recognized that the existence of this commission, and this report, will have little impact on the views of dedicated opponents of the Fraser Valley Gas Project proposal. This report deals with the technical assessment of risk, with what may be termed actual hazard. It has relied on expert knowledge and testimony, on the views of those familiar with the critical aspects of the various problems involved. By contrast, the concerns of the opponents of the proposed drilling in large part are not based on technical considerations, and thus are not capable of being reduced or allayed by expert opinion. Their perception of the risk is what is important, not what the risk actually happens to be. This became clear at the first public meeting on 12 June 1990, where objections to the proposals of the Fraser Valley Gas consortium were expressed and recorded. The views expressed mirrored what experience and the literature on energy facility siting issues suggested would be said.

Outrage is the term in common use in the literature of risk evaluation to describe this public perception of risk. Why it differs so dramatically from the technical evaluation of risk is helpful in understanding the reaction that can be expected from a technical study.

First, outrage tends to be high where the risk is involuntary, as it would be were drilling to be permitted. It is not like driving, or skiing, where risks many hundred times greater than at the workplace may be encountered, but where the acceptance of risk is entirely up to the individual. A person does not have to go skiing, but, as was said many times in the public meetings, if drilling takes place near an individual's property, he or she is willy nilly exposed to the risk of that activity, whatever it may be. That the risk is small, or even negligible, perhaps equivalent to driving five miles on the Trans Canada Highway, or skiing for twenty minutes, is simply not relevant. The drilling risk is an imposed, involuntary risk, and such risks are

[6] Illinois Department of Mines and Minerals, *Annual Report*, 1989, page 27.

inevitably seen as much more dangerous than the voluntary.

A second factor causing a high level of outrage is that the risk is artificial. The risk of a Fraser Valley resident being killed by lightning is many times greater than the possibility of a resident being killed through a drilling or gas storage accident, but the two types of risk are quite different. Lightning creates a natural risk; chance determines who will be killed. Exploratory drilling, by contrast, is the result of government and company decisions, and is thus artificial. Public perceptions are quite different in the two situations. One is accepted with equanimity, the other is not.

The third factor is that petroleum drilling is not familiar to the residents of the Fraser Valley. What is familiar is generally considered far less of a risk, and what is not familiar is generally considered to be very high risk. Bungy cord jumping from the Nanaimo River bridge may be less hazardous than driving for a half hour on the highway near Abbotsford in a December snowstorm, but the driver is surrounded by the familiar, wearing clothes, and listening to a favourite tape. Not so when standing on the outside girder of the bridge in a bathing suit, with the Nanaimo River thirty metres below.

The fourth factor is the precision with which the risk can be quantified. What is knowable, understandable, or predictable tends to be more acceptable than what is uncertain. Thus in low risk situations where it is impossible to quantify risk with a high level of precision (for example, the risk to groundwater from exploratory drilling) the lack of precision by reason of the low level paradoxically adds to the outrage, instead of reducing it.

The fifth factor is the high profile of accidents in certain industries. They become symbolic of high risk.

Unfortunately for the Fraser Valley Gas Project, the production end of the petroleum industry is in this category; the Exxon Valdez, war in Iraq — high profile, unpleasant events tend to be associated with the upstream end of the petroleum industry, and thus the perception of risk, or outrage, is high. By contrast the downstream end is not considered in the same light. Few people express more than polite surprise when told that last year ten to fifteen times as much oil went into the oceans surrounding North America by reason of used oil being put down the drain, or otherwise being improperly being disposed of on land, than went into the ocean from the gashed hull of the Exxon Valdez. One causes public outrage, the other surprise. One is a symbol, the other is not, yet to the technical expert the second may be of more concern than the first.

The list of factors on which expert risk analysts and concerned members of the public differ could be expanded fivefold; the points listed above indicate a basic difference of approach which makes dialogue very difficult, and agreement next to impossible.[7] That they do not agree is not necessarily by reason of perversity or ill will. The two approaches are based on differing premises as to what is at stake.

It is important for this point to be borne in mind when a decision on whether drilling should take place in the Fraser Valley. The fact that expert opinion does not consider such drilling to pose high risks, the fact that expert opinion believes that the potential benefits of drilling outweigh the small risk that exists, and the fact that drilling may well pose far less risks than alternatives are not matters that will result in reduced opposition to the proposals of the consortium. Historical experience elsewhere as well as in this province makes it clear that expert opinion is highly unlikely to dent the

[7] The paragraphs above are largely based on a paper of Professor P.M. Sandman of Rutgers University, entitled "Hazard Versus Outrage: Responding to Public Concern About Environmental Risk", A Speech to the American Industrial Hygiene Association, Orlando, Florida, May, 1990.

views of those who have differing perceptions about the nature of risk, whose minds tend to exclude evidence contradictory to their predetermined position and magnify evidence that supports it, and who are members of organizations that depend for their existence on a shared perception of high risk.

Unfortunately the difference in approach outlined above and in other sections of this report between public groups and "expert opinion" is poorly understood. Experts become annoyed when their opinions are ignored, or are dismissed by lay persons on the basis of what the experts "know" to be trivial or improperly assessed evidence. Public groups become hostile when experts declare the bases of their perceptions to be fundamentally irrational. Public officials become concerned, and erroneously conclude that the continuing and vehement criticism of the technical analyses is the result of technical weaknesses. The true reason is that the risks as determined by experience and the views of experts cannot satisfy those whose attitudes are based on fundamentally different perceptions as to what the problems are.

Thus the attitudes of the opponents to drilling will not be modified by further delay, more technical hearings, more consultants' reports, more information from the consortium, or by more assurances of safety by public officials. The problem lies not with the quality of the technical analysis, it lies in the fact that technical analysis cannot deal with perceptions of risk or of outrage that the opponents hold. Opponents of drilling will be satisfied only when those who are responsible for the decision on drilling accept their perceptions of risk of exploratory drilling, and reject the expert view of the validity of their perceptions.

Issues if Drilling is Not Allowed

Throughout the life of this commission there has been vigorous and organized opposition to the proposals of the Fraser Valley Gas Project consortium. This has largely been associated with the Friends of the Fraser Valley. This opposition, and the citizens group, has been of value to the commission, as it has helped identify and clarify the issues of concern, has helped identify witnesses who might have information critical of the drilling program, has helped it in determining what lines of questioning should be followed at the technical sessions, and finally has helped phrase the questions put to the witnesses. Its existence and activities have also required the consortium to justify and explain to the public and the commission matters that might otherwise have been taken for granted.

The activities of those opposed to drilling should not mask the fact that public opinion in the Fraser Valley has not been unanimously opposed to the proposal. The Friends of the Fraser Valley have some 1,000 members, mostly in the Aldergrove/ Langley area. By contrast, according to Dynamic Oil, a partner in the Fraser Valley Project consortium, more than 800 property owners, at least 270 of whom are in the Langley area, have entered into some form of contractual arrangement to allow petroleum companies to drill on their land. These people and the many others who currently support the drilling proposal have not formed a similar organization to the Friends of the Fraser Valley, and have, as far as the commission can determine, made no concerted effort to bring out people who share their views to the public meetings or technical hearings. They have been content to leave the Fraser Valley Gas Project consortium to present the case in favour of drilling. From the point of view of public opinion, there has thus been an imbalance in the coverage afforded the two opposing points of view, and very little coverage indeed of the large numbers of people with whom the commission came in contact over the summer who intended to form no firm opinion until they had had the opportunity

of examining the technical information assembled by this commission.

Given the differing levels of public activity, it is impossible to say with any precision what the numbers in the three groups might be; the last group, those who are awaiting further information before making up their minds, is probably the largest. Of the other two, those for and those against, the relative size of supporters and opponents of drilling with whom the commission had contact in one way or another is probably in the 40/60 ratio, with the larger figure representing those opposed.[8]

Reaction of Subsurface Property Rights Owners

The question is an important one to the government when determining what weight to give to public opinion. Many of those who support exploratory drilling are working farmers, with larger acreages than the estate/residential or rural/residential properties of the valley. For example, the Delta Farmers' Institute, claiming to represent the majority of working farmers in the Delta area, wrote to the commission in support of drilling.[9] Personal conversations of the Commissioner with members of the organization at an Institute meeting in early August indicated that many of these people have contact with farmers in Alberta, where oil and gas production has resulted in additional farm income. Most of these people own rights to the subsurface, and thus stand to benefit economically from exploratory drilling, production, or underground natural gas storage in a manner that the surface owner without subsurface rights does not. This raises the question of subsurface rights. There are, surprisingly, few precise figures on subsurface ownership in the area. Many surface owners in the valley are unaware that they also own subsurface rights as well. The most thorough study of the issue probably has been done by Dynamic Oil, which has informed the commission that approximately two hundred and forty thousand of the more than four hundred thousand non-urban residents of the valley own subsurface rights.[10] A consultant to the commission, Mr. Gary Runka of Runka LandSense does not doubt these estimates. Generally, those that own subsurface rights are those whose properties were part of the early Crown grants in the western part of the valley, or near the banks of the Fraser River. Later land grants reserved subsurface rights to the Crown. Thus slightly less than sixty per cent of the Fraser Valley landowners outside of urban communities are potential economic beneficiaries of exploratory drilling, production, or underground gas storage activity.[11]

The significance of this can be expected to become apparent if the proposals of the consortium are not permitted to proceed. If the consortium proposals are rejected, it would appear highly unlikely that any subsequent drilling proposal in the valley in the foreseeable future would be treated differently, and allowed. (It must be remembered that the exploratory drilling proposal of B.C. Hydro in the late seventies was also rejected.) Many of those with subsurface rights will assume, not without reason, that the decision to reject the Fraser Valley Project consortium has substantially devalued, or more likely rendered worthless, the subsurface rights

[8] At one point in early July the commission considered a public opinion poll to determine attitudes towards drilling in the valley, but was dissuaded by a member of the Friends of the Fraser Valley who doubted the accuracy of such polling. The commission remains of the view that the advice was sound.

[9] Letter of Noel Roddick, Secretary of the Delta Farmers' Institute to the Commissioner, dated August 9, 1990.

[10] Letter from Dynamic Oil to the commission dated August 14, 1990, commission library number III-71.

[11] It should be noted that some of the smaller properties may, without special arrangements, be too small for drilling by reason of the minimum distance requirements of EMPR. They will still require compensation, however, as it is possible that joint action by a number of such owners might create drilling possibilities. Further, if gas is found in a pool beneath their properties, no matter how small their properties may be, they are entitled to share in the yield of the field in proportion to their ownership share of the overall petroleum deposit.

that they now own and on which they have paid taxes over the years. From the views expressed at the commission's public meetings (particularly the hearings in Delta and White Rock) these people can be expected to be very upset. It can further be expected that they will organize and demand either to be allowed to exercise their existing rights to have drilling on their land, or, as a very much second best alternative, compensation for what will be viewed as the expropriation of their existing subsurface rights, rights that in many cases have been in their family possession for more than a century.

Although the issue at this juncture is hypothetical, it was raised a number of times this summer by Fraser Valley residents at the public meetings and in conversations with the Commissioner. The vehemence of some of those who discussed the matter was certainly the equal of the vehemence of the most ardent opponents of drilling in the valley. Thus, if it is decided that exploratory drilling should not proceed, it would appear prudent to combine any decision to reject the proposal of the consortium with a strategy to compensate or otherwise deal with the subsurface rights issue. If drilling is rejected, some thousands, if not tens of thousands, of Fraser Valley residents are likely to believe that they have suffered expropriation without compensation at the hands of the government. Their annoyance will likely be all the greater as the government decision will be interpreted as the loss of their long held legal rights in order to satisfy the concerns of other residents who have, in the eyes of the subsurface owners, no legal or technical basis for their objections to their neighbors exercising those existing rights.

The commission has not had the time to examine this question in depth; it is, as stated above, hypothetical in that at the present time the government has made no decision as to whether exploratory drilling should be permitted. However in the event the government decides that drilling should not take place, it appears that the best solution to the problem would be for subsurface rights to be purchased by the Crown. This, let it quickly be said, will not please everyone; those who believe that their properties have a higher than average chance of a discovery (human nature being what it is, most will be in this category) will no doubt be hostile to any compensation based on an average figure. An average figure will also be unsatisfactory to those with gambling instincts of whom, as the success of the B.C. Lottery Corporation attests, this province has goodly numbers. Such people hope for a major payoff[12] and are no more likely to be satisfied with a small average amount based on some overall expectation of discovery than purchasers of a lottery ticket are likely to be satisfied with an averaged payout of the grand prize to all ticket holders. A small payoff is not the purpose either of the purchase of the lottery ticket or of the agreement to drill for gas on the land.

Economists from the government can talk about average returns and irrational economic expectations as much as they care to, but the big win, even if unlikely, is why people buy tickets or enter into drilling arrangements with companies like Dynamic, or Conoco, or B.C. Gas. Such people are not going to be cheerful about the value of the payments that government economists will regard as appropriate compensation. We are again in the area of differing perceptions.

Any attempt to vary the amount to take into account more likely areas of discovery will be extremely difficult given the current state of geological knowledge of the Fraser Valley. Ironically, only exploratory drilling could provide a reliable information base for such differentiation.

[12] In this regard the value of the jackpot is substantial. The Fraser Valley Gas Project consortium has put forward the figure of 14 million dollars over a thirty year period as an expected return of a 14 bcf gas well. Fraser Valley Gas Project, Summation, page 34.

Even establishing a satisfactory estimate of the total value of all of the subsurface rights in the valley, needed to establish average figures for compensation, will be a difficult task. The payments made to the government for permits and leases by the Fraser Valley Gas Project consortium members were, in the commission's opinion, higher than might have been the case had the consortium been in existence prior to the bidding and the members not bid against one another. This, however, is speculation. The only reliable market guide to the value of petroleum or storage values in the area are such sales, and the sales of privately held subsurface rights that have taken place recently. Compared to prices paid in the Peace River, the prices paid in the Fraser Valley were high, and thus indicate that Fraser Valley leases and permits are valuable commodities. They also suggest that any buyout by the government of subsurface rights may run between one hundred and two hundred million dollars.

A word of caution is also in order with respect to who should receive any such compensation. As mentioned at the outset of this section, a surprising number of Fraser Valley residents are not aware that they own subsurface rights. (Conversely, the commission came in contact with many who assumed that subsurface rights and surface rights always go together, and who were unhappily surprised to be informed that their rights did not extend below the surface). Determining who owns subsurface rights, particularly if those subsurface rights were granted with the original Crown grant but separated from the surface rights by some subsequent owner, will in all likelihood be a major research project, and take some years to complete. Informing those surface owners who mistakenly believe they own subsurface rights that they are not entitled to payments like their neighbors will be another thankless task for the government.

Reactions Elsewhere

The comments above with respect to public opinion are confined to the Fraser Valley. Reaction elsewhere will also occur, and may in the long run be even more important. For instance, residents in other parts of the province that produce energy, or are impacted in some way by other developments such as road construction, mining, forestry, or waste disposal siting, will likely regard a decision not to drill in the Fraser Valley as lending support to their own demands for greater local support and control. If the decision results in some alternative decisions, such as, for example, expansion of the Westcoast transmission system, those who may in some way bear costs or suffer inconvenience or bear the risks of the expansion will understandably wish to mobilize local public opinion to achieve their objectives in a manner similar to the opponents of drilling in the Fraser Valley. Arguments of necessity and convenience, or province-wide benefit, are far less likely to be persuasive or accepted following the rejection of drilling in the Fraser Valley.

The likely reactions of some other groups to a decision not to permit drilling are mentioned in the section of this report dealing with possible customer demand restrictions. Briefly, they are those whose interests have been affected by the Vancouver Island Gas Pipeline decision, such as property owners on Vancouver Island who object to pipeline location on their properties, forestry companies who object to the restrictions placed on their ability to obtain the most economical fuels for their Vancouver Island pulpmills, the Federal Government which had little enthusiasm for providing financial support, and in particular, GVRD municipal officials, both elected and unelected, who opposed the routing of the natural gas pipeline through the GVRD's Coquitlam Watershed. A decision not to allow drilling would likely not be perceived as negatively as a decision to curtail customer hookups. However, to some it will likely be perceived as either a step in that direction or as a decision which increases the likelihood of such a situation developing.

Reactions of the Business Community

Finally there is the business community, whose interests in and reactions to the consortium's proposals this commission has specifically been instructed to consider.[13]

It is clear from B.C. Gas' efforts to switch industrial customers from firm to interruptable power that the delivery system in winter is tight, and that this situation will get worse as the steady increase in customers of some 5% cumulative per year takes place. If conditions were to deteriorate, the business community will be well aware from press comments, not to mention their in-house public affairs officers and outside consultants, that industry is not likely to be first on the list when it comes to guarantees of delivery. Indeed, other than those with backup systems based on diesel or other fluid hydrocarbon fuels, such as hospitals, the list that industry will head will be the list of those who will first suffer natural gas cuts. There is thus uncertainty as to supply, which at the present time, by reason of the vigorous past efforts of the government, Crown agencies and B.C. Gas to expand natural gas use, and to expand supply, is very much a back burner concern. However this might change if there were a decision not to allow drilling in the Fraser Valley. A decision not to allow exploratory drilling might well be interpreted by the business community as a weakening of government resolve to guarantee future supply, and this in turn could affect the business confidence of those whose industries depend on reasonably priced natural gas on an uninterrupted basis.

If such a concern develops, such business interests are likely to contrast the situation here with the situation in Washington State and Oregon, where storage facilities to assure winter supplies, and to reduce the possibility of interruptable power, have been developed and are likely to be expanded. The business community also is well aware of the effects of free trade on energy sales across the border; price discrimination against U.S. energy buyers is largely a thing of the past.[14] Thus business in B.C. is well aware that the provision of storage facilities in Washington and Oregon, and the lack of such facilities here, may also result in B.C. gas in the future selling at lower rates in those two states than in the province in which it is produced. When this is coupled with the possibility of interrupted supply in winter, B.C. business may well have very serious concerns.

The prospect of lower gas prices in the U.S. northwest, and a higher risk of interrupted supply for businesses in British Columbia, may come about in any event. It is quite possible that exploratory drilling in the Fraser Valley will lead to no commercial finds of natural gas, and no formation suitable for storage. Thus some have advanced the argument that as finds of natural gas and of storage formations are unlikely, a decision one way or another will not affect business attitudes in the province.

The commission disagrees. If the drilling takes place and nothing is found, the psychological business climate will likely be different from what it would be if nothing were found because no drilling was permitted. The difference to the psychological climate will be in the commitment demonstrated by the government to continue with its aggressive policy of promoting the use of gas. Not all decisions result in direct benefits. A decision to allow drilling may

[13] Terms of Reference 2 (g).

[14] A major U.S. objective in the free trade negotiations was to obtain access to Canadian energy supplies, and to avoid being subjected to the discriminatory treatment U.S. buyers of Canadian energy (and in particular, Washington and Oregon buyers of B.C. gas) received in the 1973 period, during the OPEC oil embargo. When questioned by Commission Counsel MacAdams, EMPR officials spoke guardedly at the technical hearings on B.C.'s current ability to differentiate between local and export customers. The Free Trade Agreement, plus the 1985 federal/provincial agreement on energy pricing, has probably ended any serious possibility of favouring domestic B.C. consumers.

very well result in nothing found; but such a decision will indicate resolve, and indicate that other measures to obtain secure supply for the business community will be pursued.

It should quickly be added that the B.C. business community dependent on reliable supplies of reasonably priced gas is not poised to pack up and leave. However the impact of decisions which may leave the impression of future higher prices, and future insecurity of supply, needs to be carefully considered by government before any decision to allow or refuse the Fraser Valley Gas Project proposal is made.

The comments above are not meant to be definitive, but they suggest that some thought to these wider ramifications of a government decision to reject drilling in the Fraser Valley is in order. They are listed here simply to indicate that a decision not to proceed with drilling would have some far reaching consequences which should be properly assessed and taken into account.

Issues if Drilling Is Allowed

The paragraphs in the section above outline some of the difficulties from the point of view of public opinion that might arise were the government to disallow drilling in the Fraser Valley. For the sake of balance a few paragraphs should be devoted to some of the public opinion issues that might arise were the government to allow the exploratory drilling of the Fraser Valley Gas Project consortium to proceed.

First, much of the hostility currently directed against technical experts and the Fraser Valley Gas Project consortium will be transferred to the government. The hostility to the commission's report commented on above also will be diverted to the government. If there is belief that the decision to permit drilling might be reversed, this hostility can be expected to intensify.

However, if the decision appears to be firm and unchangeable and it is clear that the go/no go debate is over, there will be a strong possibility of successful mediation and compensation discussions, mentioned in this report in Chapter 13. There are many examples of such activities being successful in other jurisdictions, a recent example being the Caroline Swan Hills development in Alberta. Such mediation and compensation would provide benefits from the drilling project to those who currently believe that the uneven burden of risks and benefits of the drilling program has placed them in a losing position.

The prime requirement for successful negotiations and activities of that type is a clear recognition that the drill/no drill battle is over, and that drilling is to proceed. Only then will discussions as to how it can proceed in an acceptable manner, and discussions as to what trade-off benefits might be provided, likely be successful.

This chapter is divided into three sections — a general profile of the characteristics of the Fraser Valley, a description of Fraser Valley geology, and a history of oil and gas drilling activity in British Columbia, the Fraser Valley and Washington State. It is intended to provide the reader with a general understanding of the land use, geological and historical environments of the proposed drilling program.

Profile of the Fraser Valley

This section outlines the important physical, social, economic and land use characteristics of the Fraser Valley. Specifically, this section describes the Fraser Valley's geography, terrain, climate, vegetation, population growth, economic structure, agricultural industry and the various land uses and land use issues which exist in the area. Its purpose is to provide the reader with knowledge of both the character of the region and the many changes taking place within it.

Overview

The entire study area of the commission is a large and highly diverse region. It contains the urban centre of Greater Vancouver, the largely rural areas of the Fraser Valley, as well as mountainous areas to the north. It contains some 1.8 million people who use the land base for all forms of residential, economic and recreational endeavours.

Mr. Gary Runka, former chairman of the Agricultural Land Commission and a land use consultant retained by the commission, describes the diversity of the Fraser Valley region:[1]

> *The rural portions of the region provide significant raw forest materials, our urban and rural water supplies, plus or minus 80 agricultural commodities, a wide range of attractive outdoor recreation opportunities, rural residential options, rural lifestyles, and highly-productive fish and wildlife habitat. Together, the rural and urban portions of the region are home to over one-half of B.C.'s population.*

Geography

The Fraser Lowland is a large area of flat and rolling land located in the southwest corner of British Columbia, Canada and in the adjoining northwest corner of Washington State in the United States. The Lowland represents a triangular area of approximately 2,600 square kilometres. It extends from Hope in the east to the Strait of Georgia in the west, and is bounded by the Coast Mountains in the north and the Cascade and Chuckanut Mountains in the southeast (Figure 16).

The area of land under consideration by the commission comprises the Canadian portion of the Fraser Lowland.[2] The area includes only onshore territory, or land above the high water mark. Potential sites

[1] Transcript, pages 115-116.

[2] This is not entirely accurate. One of the exploratory well sites, the Murray Creek site, is very close to the American boarder. Seismic exploration suggests that if a gas field, or a potential gas storage formation, exists in this area, it would extend across the U.S./Canadian boundary. The commission kept Washington State officials informed of its activities, and wishes to acknowledge with thanks the willing cooperation of officials of the state, which included the production of documents and other information, as well as testimony at the technical hearings of Mr. William S. Lingley, Regulatory Programs Manager, Division of Geology and Earth Resources, and Dr. S. Palmer, of the Washington State Department of Natural Resources.

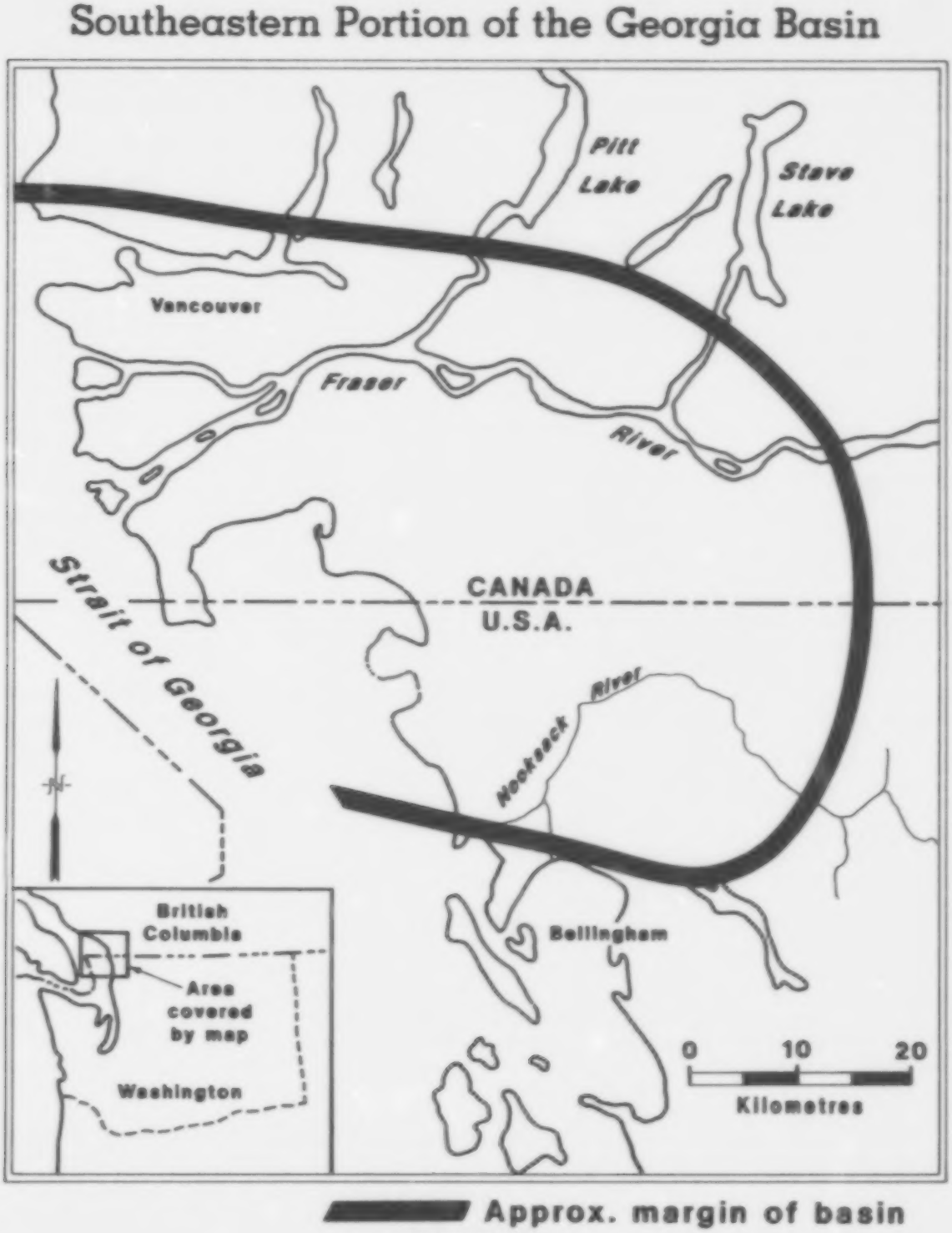
Southeastern Portion of the Georgia Basin
Pitt Lake
Stave Lake
Vancouver
Fraser River
CANADA
U.S.A.
Strait of Georgia
Nooksack River
Bellingham
British Columbia
Area covered by map
Washington
0 10 20
Kilometres
Approx. margin of basin

FIGURE 16

in the Strait of Georgia and in the various bays and inlets around the Fraser Valley were not within the area assigned to the commission. A federal moratorium on all offshore drilling has been in place in British Columbia since 1972. The provincial government placed its own moratorium on offshore drilling in early 1989.

The areas in the Fraser Lowland where most interest has been expressed in oil and gas drilling are the rural residential and largely agricultural areas lying to the south and east of the densely-populated Vancouver core. At the present time, eight oil companies hold provincial petroleum tenures in the municipalities and districts located to the east and southeast of Vancouver. The current proposal of the Fraser Valley Gas Project calls for the drilling of one well in the Municipality of Delta and two wells in the Township of Langley. The commission, therefore, focused much of its inquiry on these areas of the Fraser Lowland, although the possibility of later exploratory drilling elsewhere was also considered, as far as that was possible without a proposal or proponents.

The geographical terms of reference encompassed a very large area. These terms of reference are set out in Appendix A.

This area is shown in Figure 1 at the beginning of this report, and includes the downtown area of the City of Vancouver, the Fraser Valley, the mountainous areas north of Vancouver and the Fraser Valley, as well as the southern tip of the Sechelt Peninsula. The eastern boundary is slightly to the west of Hope.

In terms of regional administrative areas, the territory under the terms of reference includes virtually all of the Greater Vancouver Regional District, the entire Central Fraser Valley Regional District the southern portion of the Dewdney-Alouette Regional District, and small southern portions of both the Sunshine Coast and Squamish-Lillooet regional districts. For practical purposes, the area of concern is the area popularly known as the Lower Mainland.

Terrain

The terrain of the Fraser Valley varies considerably, depending upon factors such as bedrock, surficial materials and drainage history. The lowland area of the Fraser Valley is generally a dissected, late Tertiary erosion surface. The terrain consists of flat to rolling land, with an elevation ranging from sea level in the valley bottom to upwards of 300 metres in the uplands north of the Fraser River. In the uplands south of the Fraser River, the land is flat to rolling and reaches up to 120 metres in elevation. The flattest lands are found in the delta area in the west of the Fraser Valley, while hilly and mountainous terrain is found in the east and the north. In the lowest areas of the Fraser Valley, the land is dyked against the sea and river waters, as it is in the Pitt River area.

Climate and Vegetation

The climate of the Fraser Valley is characterized by moderate, dry summers and mild, rainy winters. The climate is influenced by the Pacific Ocean, which produces relatively small variations in seasonal temperatures, as well as moderate to heavy levels of precipitation.

In the summer months, high pressure systems usually extend over the coast to produce frequent sunny weather. In winter, low pressure systems from the Pacific Ocean create a succession of cloudy and rainy conditions.

Variations in these general climatic patterns occur throughout the Fraser Valley, particularly at higher elevations. The Coast Mountains which bound the Fraser Lowland to the north have the highest totals of rain and snow in Canada, reaching 350 centimetres annually. At lower elevations in the Fraser Valley, annual precipitation is 75 centimetres

annually, and snowfall is lighter. Average precipitation for the whole region is approximately 100 centimetres. The frost free period for the Fraser Valley is generally in excess of 200 days, but declines as one moves further away from the ocean.

The Fraser Valley contains a full range of soils, including organic and mineral soils with different depths, textures and drainages. This soil range greatly affects land use in the region.

Native vegetation in the Fraser Valley reflects the warm temperatures at lower elevations. The lower elevations comprise predominantly coastal Douglas fir trees, western hemlock and western red cedar. Most of the natural tree cover in the lowland has either been harvested or strongly altered by land clearing. At higher elevations, the cooler and moister climates support extensive forested areas, containing western and mountain hemlock. These areas in turn support considerable industrial activity in the region.

Population

The entire Fraser Lowland is a relatively densely populated area of land that is home to over one-half of the 3.1 million people of British Columbia. Currently, some 1.8 million people live in the entire Fraser Lowland area within the commission's terms of reference.[3]

The Fraser Lowland contains most of the fastest growing municipalities in the province, and these high growth rates are expected to continue into the future. By the year 2000, the population living in the Fraser Lowland, including Greater Vancouver and the eastern Fraser Valley is expected to increase to 2.1 million, and by the year 2015, to 2.7 million people. In British Columbia, the population in 2015 is forecast to reach 4.6 million.[4]

Economy

The economy of the Fraser Lowland is represented by a mixture of service, manufacturing and resource-based industries. In past years, both people and industry have expanded eastward from the Vancouver core. These outward trends are expected to continue in the future, and will be hastened by improved transportation linkages such as eastward extensions to the SkyTrain automated light rapid transit system. The economic composition of the entire Lower Mainland, and the eastward pressures on the land base are described in a 1989 report prepared by the Ministry of Regional Development:

> *Most of the areas in the Lower Mainland are closely inter-related, with no clearly defined boundaries on places of employment, expenditure or residence. In general terms the densely populated urban core has been steadily expanding from Vancouver, pushing before it the suburban neighbourhoods of single family dwellings. The latter now are firmly established in Pitt Meadows-Maple Ridge and Matsqui-Abbotsford areas and have moved even father eastward. Industrial activity has also moved outward in search of larger sites and reduced congestion. Valuable farmland now enjoys Legislative protection; hence, heavily populated suburban areas also support considerable agricultural activity. Beyond the pervasive influence of Greater Vancouver, the primary resource industries are of greatest importance. The forest industries are particularly significant in . . . Kent-Harrison and Mission areas . . . In the Chilliwack area, agriculture is the dominant resource activity.*
>
> *The relative importance of the various industries is approximated by the*

[3] This includes 1.5 million people in the Greater Vancouver Regional District and a further 300,000 people living primarily in the eastern portions of the Fraser Valley.

[4] Population figures used in this section were derived from "British Columbia Regional Hospital District Population — Census and Estimates", Planning and Statistics Division, Ministry of Finance and Corporate Relations, Victoria, June 1990, as well as "Greater Vancouver Key Facts", GVRD Development Services, Burnaby, July 1990.

number employed in each. In 1986 the composition of the experienced labour force was as follows: agriculture 2.1 per cent; forestry (logging) 0.9 per cent; fishing and trapping 0.4 per cent; mines and quarries 0.4 per cent; manufacturing 12.4 per cent; construction 6.5 per cent; transportation, communication and other utilities 9.7 per cent; trade 18.4 per cent; government services 5.7 per cent; and other tertiary (service) industries 43.5 per cent.[5]

Agriculture in the Fraser Valley

A mild climate, favourable soils, flat terrain, and the proximity to a major market all contribute to making the Fraser Lowland the leading farming district in the province. In terms of farm cash receipts, the entire Fraser Lowland region had farm sales of approximately $600 million in 1985, or 56 per cent of the British Columbia total. The Fraser Valley provides land for many different agricultural products, including cattle, dairy, poultry, hogs, tame hay, fruit and vegetables, potatoes, and nursery crops. In addition, a significant amount of space is today devoted to greenhouses, and this trend is expected to continue.

The importance and intensity of agricultural operations in the region is described in the British Columbia Regional Index:[6]

> *Although the Mainland/Southwest Region contains the largest urban centre in British Columbia, and thousands of acres of farmland have been lost to other uses over the years, it remains the leading farming district by a wide margin. Of 5,751 census farms (with sales of $250 or more), over 26 per cent reported cash receipts exceeding $100,000, and 250 farms had gross sales over $500,000 in 1985. In view of high average returns and low average size, farming operations may be described as intensive and highly specialized . . .*
>
> *The most intensive farming activity (that which produces the highest return per acre) is found closest to — or within — metropolitan Vancouver. Analysis of historical records indicates a gradual outward movement from Vancouver over time, with those sectors having the biggest land requirements (dairy and beef cattle) becoming concentrated at the outer limits of the region or moving right out of the Lower Mainland.*

Land Use Description

For the purposes of general land use description, consultant Gary Runka divided the Fraser Valley into five distinct areas.[7]

Urban Core

The Urban Core includes downtown Vancouver and the immediate outlying areas of South Vancouver, the North Shore, Burnaby, Port Moody, New Westminster and parts of Richmond. Land use in the core is oriented towards densely populated residential and commercial buildings and a varied and intensive transportation system.

Northern Mountain System

The second area is the Northern Mountain System, Howe Sound and Sechelt Peninsula. This area is a key source of water supply for the Lower Mainland population. Opportunities for forestry and outdoor recreation also exist in this area, and fisheries habitat is extensive. Rural residences occupy land in the lower elevations of the area as well as on the Sunshine Coast.

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[5] Ministry of Regional Development, *British Columbia Regional Index*, 1989, pages 97-98.

[6] Ministry of Regional Development, *British Columbia Regional Index*, 1989, pages 100-101.

[7] These are the Urban Core, the Southeastern Mountain System, the Northern Mountain System including Howe Sound and the Sechelt Peninsula, the Valley Uplands, and the Valley Lowlands and Foreshore.

Changes in land use include more intensive forest management and outdoor recreation activities. Greater residential development at lower elevations is also occurring, but is meeting with increasing public opposition from existing residents. The main land use issues in the area include watershed protection, the impact of residential development on forested space, and protection of aquatic and terrestrial habitats.

Southeastern Mountain System

The Southeastern Mountain System represents the third distinct area in the study area. Land use in the Southeastern Mountain System is characterized by an integration of wood harvesting and production, outdoor recreation, and fish and wildlife habitat. Military facilities and rural residences also represent a significant component.

Recent land use changes have included more intensive forest management, and a greater integration of outdoor recreation opportunities with wildlife habitat protection and enhancement. Important land use issues in the area include old growth harvest versus wilderness preservation, rural residential growth, greater outdoor recreation opportunities, management of the floodplain, and fish and wildlife habitat conservation.

Valley Uplands

The fourth area is the Valley Uplands. This region includes an elevated area north of the Fraser River, and a large elevated area south of the Fraser River. The upland area has historically been dominated by agriculture, but also includes forestry and rural and estate residential uses. Fish and wildlife habitat are extensive as well as outdoor recreation opportunities and aggregate extraction of available material.

The major land use change in the area is the conversion of agricultural land to rural and estate residential uses. Within the agriculture industry specifically, there has also been a conversion from soil bound to non-soil bound agriculture, such as poultry, mushrooms, hogs and greenhouses. Horse oriented operations, including pleasure horses, commercial horse breeding and training and boarding have also increased over the past ten years. As aggregate supplies are depleted in the uplands, land use is shifting to other opportunities.

The important land use issues in the uplands include the protection of rural lifestyle, the quality, quantity and use of groundwater, the protection of floodlands, the appropriate location of intensive agricultural operations, soil and water conservation, and fish and wildlife habitat. A current and hotly debated issue in the uplands is the location of golf courses.

Valley Lowlands and Foreshore

The Valley Lowlands and Foreshore comprise the final area of study. This region includes areas in and around the Fraser River, Sumas River, and Boundary Bay. This area is dominated by soil bound agriculture on highly productive agricultural land. The foreshore, moreover, represents an internationally important habitat for fish and wildlife. Residential use is significant but is less obvious than in the Valley Uplands. Large areas of land are also occupied by transportation routes, utility corridors, and some industrial operations.

Land use within the lowlands and foreshore has been more stable than in other areas. As elsewhere in the region, there has been a shift from soil bound to non-soil bound agricultural operations, as well as some conversion of agricultural land to residential and recreational uses.

The most important issues in the lowland are farmland preservation and fish and wildlife protection. A significant issue currently is the location of golf courses in the Agricultural Land Reserve. This issue is a more serious one than in the upland, because of the higher capability land in

the lowland area and the closer association with the existing agricultural community.[8]

Rural Lifestyle in the Fraser Valley

Rural lifestyle is an important defining characteristic of the Fraser Valley. Development which is seen to reduce the rural character of the Fraser Valley will be opposed by residents in the area. The greatest threats to this rural character have been the increasing residential and commercial development in the Fraser Valley, as well as the development of recreational facilities such as golf courses.

Mr. Runka described the importance that many Fraser Valley residents place on a rural lifestyle:[9]

> *Based upon experience gained from several years of work in the region, including various recent Fraser Valley projects, it is my opinion that protection of rural lifestyles is a key issue at present. The rural lifestyle protection concern transcends many Fraser Valley upland users' interests, including food producers of various kinds, rural and estate residential, and outdoor recreation land users.*

Mr. Runka continued:[10]

> *Most are concerned with maintaining environmental quality, pastoral, agriculturally-oriented landscapes, fish and wildlife habitat, and distance from the urban core. Consequently, there is often a resentment of any intrusion, change of use, or increase in noise or traffic that could interfere with their chosen rural lifestyle.*

Mr. Runka further discussed rural land use conflicts which have taken place in the Fraser Valley, and which are likely to continue:[11]

> *My experience in the rural communities of the Langley uplands, as well as in the remainder of the Fraser Valley, suggests a constant struggle between neighbouring uses and within communities to seek and retain compatibility of land and water use. Example: greenhouse versus rural residential interface; fish habitat/rural residential-agricultural interfaces; horticulture, berry fruits versus aggregate extraction interface.*
>
> *Within such a setting, the introduction of what is perceived as a new foreign use will invariably be regarded as an intrusion into the already significant maze of potential conflicts and rural lifestyle interference.*

Geology

This section describes the geological conditions required for the accumulation of petroleum in the subsurface, a detailed description of the geological characteristics of the Fraser Valley and Georgia Basin, and finally an assessment of the occurrence of hydrogen sulphide (sour gas) in the Fraser Valley area.

Geological Conditions Required for the Accumulation of Oil and Gas

Three factors are required for the accumulation of oil and gas in the subsurface. These are the initial source rock that would produce oil and gas, the reservoir rock that would be filled with oil and gas, and the geological trapping conditions that would contain the oil and gas and keep it from escaping.

Sources for Oil and Gas

The first requirement for oil and gas is source rock that has a high quantity of

[8] Gary Runka, "Land and Water Use Overview", August, 1990. This document is Exhibit T-2.
[9] Transcript, page 126.
[10] Transcript, page 126.
[11] Transcript, pages 146-147.

hydrogen and carbon atoms (hydrocarbons). Oil and gas originate from organic material deposited millions of years ago in sedimentary rock. The organic theory of petroleum accumulation holds that oil and gas are of marine origin.[12] For millions of years marine life has fallen in a steady stream to the bottom of the ocean. Although most is eaten or oxidized along the way, a portion of residue remains intact and becomes entombed in the ocean floor, where it is gradually broken down into material rich in hydrogen and carbon.

As sediment on the bottom of the sea floor builds, this rich organic material is squeezed into hard shales and is heated at high subsurface temperatures. Between temperatures of 150 and 500 degrees F, the organic material recombines chemically to form different kinds of hydrocarbon molecules. Oil and gas are the results of this organic cooking process. Consequently, the presence of rocks that have a high concentration of hydrocarbons indicates a potential existence of oil and gas in an area.

Reservoir Rock

A second requirement for oil and gas is the presence of rock which acts as a reservoir for the petroleum deposit. A petroleum reservoir or oil pool is not a liquid in an underground cavern, as the terms may suggest. Rather, a reservoir is mostly solid rock with tiny holes or pores. In order to be capable of holding oil or gas, the reservoir rock generally must have a porosity of at least 10 per cent — that is, at least 10 per cent of the rock volume must be pore space.[13]

Along with porosity, the reservoir rock must also be permeable. Permeability refers to the connection of the pore spaces in the rock. This connection is required for oil and gas to move smoothly through the structure for the purposes of petroleum extraction.

Reservoir rock also usually contains salt water along with oil and gas and other hydrocarbons. Fluids in a reservoir rock are found in layers, with the lightest on the top (gas), the oil in the middle, and the heaviest on the bottom (brine water). The presence of water in the rock is often advantageous for extraction purposes, as water pressure can supply the force to push the petroleum out of the reservoir rock and to the surface, making pumping unnecessary.

Traps

The third requirement for the accumulation of oil and gas is a trap that prevents oil and gas from migrating throughout the subsurface. Generally a thick seal or caprock is required to contain such movement. There are two general types of geologic traps — structural and stratigraphic.

Structural traps are formed by deformations in the subsurface, through natural folding and faulting processes of the land. Plate tectonics create the ongoing pressures in the subsurface which produce various structural trapping conditions. Common structural traps include anticlinal traps, fault traps and dome plug traps.

Stratigraphic traps are those structures that have a sudden updip termination of porosity and permeability. This is usually caused by an uneven formation of sediments (lenticular trap), or by an erosion of porous deposits and an overlaying of impermeable caprock (unconformity trap).

Geological Conditions in the Fraser Valley

The Georgia Basin and Fraser Valley Areas

The Fraser Valley represents a surface portion of a relatively small geological depression known as the Georgia Basin.

[12] M. Gerding ed., *Fundamentals of Petroleum*, University of Texas Press, 1986, page 14.

[13] Ibid., page 2.

As depicted in Figure 17, the Georgia Basin is a northwest-southeast oriented structure, and comprises largely the waters and sub-surface of the Strait of Georgia.

The west side of the Basin includes low-lying coastal areas of eastern Vancouver Island, extending from Sayward on Johnstone Strait in the north to Victoria in the south. It includes Hornby and Denman islands as well as all the Gulf Islands.

The east side of the Basin includes parts of numerous islands southward to Malaspina Peninsula, and the thin strip of coast extending further to Howe Sound.

The Fraser Valley represents the southeast, surface portion of the Georgia Basin. The margin of the geological basin is shown in Figure 16, and covers the Lower Mainland of British Columbia as far east as Sumas, as well as a portion of northwest Washington State, north of Bellingham. Around the margin of the basin, older Tertiary rocks, the anticipated subsurface in the Fraser Valley, are exposed at the surface. The sandstone cliffs at Stanley Park's Siwash Rock are examples of such exposures.

Geological History of the Fraser Valley

For the past 160 million years, the structure of the Georgia Basin has been controlled by plate tectonics. This activity has involved the North American tectonic plate being underthrust by other plates moving towards North America from the west and southwest. This in turn has caused uplift on the North American surface.

Between 65 and 80 million years ago, a major mountain building episode occurred in the Fraser Valley area, which led to the creation of the Coast and Cascade Mountains. This uplift process has led to the formation of geological structures in the Fraser Valley which could provide the required trapping conditions for oil and gas.

Following this mountain building period, sediments were deposited into the Georgia Basin via ancestral rivers from the Coast and Cascade mountains, as well as ancestral Vancouver Island. These sediments were deposited in both nearshore marine and deltaic environments. Most of the sediments in the Fraser Valley are considered to be nonmarine in origin.

Dr. R.M. Bustin, a professor of Geological Sciences at the University of British Columbia, describes the formation and composition of early strata in the Fraser Valley:[14]

> *Southwestern mainland British Columbia and adjacent parts of northwestern Washington include a thick succession of Upper Cretaceous and Tertiary strata which were deposited in a structural reentrant in the Coast and Cascade mountains. These strata form the eastern margin of the Georgia Basin, an Upper Cretaceous and Tertiary structural sedimentological basin(s) that at various times encompassed Georgia Depression, Comox, Nanaimo, and Suquash basins of eastern Vancouver Island, the Gulf Islands and the Whatcom Basin (Bellingham Basin) of northwest Washington (Miller and Misch, 1963; Johnson, 1984; Bickford and Kenyon, 1988; England, 1989). Georgia basin includes a succession at least 6 km thick of marine, fluvial-deltaic and alluvial sediments. The basin embraces strata assigned to the Nanaimo Group on Vancouver Island and the Gulf Islands; the Burrard, Huntingdon and Kitsilano formations of southwestern mainland British Columbia; the Chuckanut Formation of northwestern Washington; and an unnamed subsurface succession more than 4.5 km thick in the Fraser Lowland.*

[14] R. M. Bustin, "Stratigraphy, Sedimentology and Petroleum Source Rock Potential of the Georgia Basin, Southwest British Columbia and Northwest Washington State", Geological Survey of Canada, Paper 90-1F 1990, page 103.

Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources
PIPELINES
and
SEDIMENTARY BASINS
of
BRITISH COLUMBIA
Km 0 40 80 120 160 200 Km
LEGEND
GAS PIPELINE
OIL PIPELINE
PRODUCING
PROSPECTIVE
INDEX TO
SEDIMENTARY BASINS
A WESTERN CANADIAN
B WHITEHORSE
C BOWSER
D NECHAKO
E QUESNEL
F FERNIE
G QUEEN CHARLOTTE
H TOFINO
I GEORGIA
Prince George
Kamloops
Cranbrook
Vancouver
Victoria
Prince Rupert
WASHINGTON

FIGURE 17

More recently, between 12,000 and 25,000 years ago, the Fraser Glaciation changed the configuration of the near surface geology of the Georgia Basin. Today much of the Fraser Valley is covered by thick glacial sediments, as well as sediments from the Fraser River.

Subsurface Geology of the Fraser Valley

It is important to remember that the Fraser Valley is still a frontier area for the purposes of petroleum exploration. Although much information has been collected over the years relating to the structure and composition of the subsurface, characteristics such as the age of the subsurface are still poorly known.[15] Despite these gaps in knowledge, available data show that the potential exists for dry, sweet natural gas in the subsurface.

At the technical hearings Mr. John MacRae, Director of Petroleum Geology at the Ministry of Energy, Mines and Petroleum Resources, described the subsurface geology of the Fraser Valley:[16]

> *This geological structure is filled with at least 6,000 metres of sandstones, shales and siltstones, ranging in age from 85 million years up to about 15 million years before present. In geological terminology, these rocks would encompass the late Cretaceous to the Miocene age.*
>
> *The total sedimentary rock package thickens from a zero edge near Chilliwack, at the eastern end of the lower mainland, to thicknesses in excess of 4,000 metres near Tsawwassen, and in fact even greater thicknesses as we get into offshore portions of the basin.*

Bustin, in his technical submission to the commission,[17] describes the geology of the Fraser Valley subsurface in greater detail:

> *From east to west across the Fraser Lowland the stratigraphic succession thickens from near Abbotsford where there is about 670 m of strata overlying granitic basement and in excess of 4400 m in the Point Roberts area. For the most part the strata are comprised of interbedded fine to coarse-grained sandstones, green, red and black shales and siltstones and rare thin seams of coal and lens and beds of conglomerate up to 2.5 m thick. The sandstones average about 4 m thick whereas the finer grained shale and siltstone intervals are up to 60 m thick. The sandstones are evenly distributed throughout the succession. The stratigraphic succession appears to be mainly nonmarine and, at least in the Point Roberts and Sunnyside wells, such an interpretation is supported by the absence of marine microfossils (Hopkins, 1966). Most sandstones either fine upwards or show little variation in grain-size (as interpreted from the wire line logs) and are probably fluvial and alluvial deposits. Less commonly sandstones occur which display distinct coarsening upward trends; they are up to about 10 m thick and are interpreted as beach and/or bar deposits. Shales underlying or overlying the beach sands are probably transitional marine in origin but the majority of the shale/siltstone intervals are considered nonmarine.*

Oil and Gas Sources in the Fraser Valley

Geochemical analyses indicate the potential for generation of dry, sweet gas from basin source sediments. In his technical submission, Dr. Bustin describes a moderate potential for significant natural gas reserves:

> *For the most part the stratigraphic succession in the Fraser Lowland is immature with respect to oil generation although mature source*

[15] Exhibit T-34, page 8.
[16] Transcript, page 87.
[17] Exhibit T-34, page 7.

> *rocks occur in the most deeply buried part of the basin and adjacent igneous intrusions. Based solely on the characteristics of the source rocks there exists a moderate probability of substantial natural gas and a low probability for liquid hydrocarbons.*[18]

Mr. John MacRae also stated the potential exists for a natural gas in the Fraser Valley:[19]

> *The geological and geophysical data that the Ministry has in its possession at this time suggests that there is significant natural gas potential in other sedimentary basin areas, including the Fraser Valley portion of the Georgia Basin.*

Reservoir Rock in the Fraser Valley

Reservoir rock of excellent quality has been encountered in the Fraser Valley. In the 1950s, the Royal Can Van-Tor Kuhn #1 well (1,585m) and the Hercon Key Evans #1 well (2,397m) encountered porous, water bearing sandstone zones with high porosity values of 18-24%. As previously indicated, geologists believe that reservoir rock with 10% porosity is required for petroleum extraction purposes.

Traps in the Fraser Valley

The geophysical and surface structural data indicate the likelihood of encountering structural and stratigraphic traps in the area.

A fundamental requirement for a hydrocarbon reservoir — impermeable layers of caprocks or reservoir seals, has not been extensively documented in the Fraser Valley. However, it is expected that the occurrence of alternating subsurface layers of sandstone, shale and siltstone will provide opportunities for adequate caprock development.

John MacRae stated:[20]

> *The overall structural history of the Georgia Basin has been controlled and is, of course, at this point also being controlled by a much larger geological phenomenon — that of plate tectonics. Plate tectonics has affected the western margin of North America for at least the last 160 million years.*
>
> *In a general sense, what this activity has caused is for the westward tectonic plates to be subducted or pushed under the North American continent. This becomes important within the context of the Georgia Basin in that geologically this provides opportunity for the creation of geological structures. Geological structures, of course, are a prerequisite of any oil and gas deposit being found in any basin.*

Is Hydrogen Sulphide Present in the Fraser Valley?

A major source of concern at the public hearings, and a major concern of the commission was the possibility of exploratory drilling or subsequent drilling related to exploitation of gas reserves or storage encountering sour (hydrogen sulphide) gas. Hydrogen sulphide (H_2S) is an extremely toxic gas that poses a health threat to humans. When found in concentrations in excess of 0.1% by volume, H_2S can cause respiratory paralysis and asphyxiation. Hydrogen sulphide is also dangerous because it is heavier than air, and will remain at ground level following a well blowout. Hydrogen sulphide, however, is found in many reservoirs where petroleum exploration occurs, such as the Alberta oilfields. Special care must be taken when hydrogen sulphide is known to be present in the subsurface.

[18] Exhibit T-34, page 18.

[19] Transcript, page 86.

[20] Transcript, pages 88-89. See also Exhibit T-2, Tab 3, page 16.

In the Fraser Valley, there is no indication that hydrogen sulphide is present in the subsurface. The commission asked Dr. Bustin of the Department of Geological Sciences at UBC to examine specifically the potential of hydrogen sulphide being found in the Fraser Lowland. Dr. Bustin's conclusions are as follows:[21]

> *Based on currently available data the potential of significant quantities of H_2S in the Fraser Lowland from organic sources is extremely low for the following reasons:*
>
> 1. *The type of organic matter in the Fraser Lowland is mainly Type III which characteristically contains little sulfur.*
> 2. *Hydrogen sulphide is generally considered to be generated at relatively high levels of maturation (high temperatures). Strata in the subsurface of the Fraser Lowland analyzed to date have not reached the levels of maturation required for peak H_2S generation.*
> 3. *Hydrogen sulphide bearing gases are invariably associated with carbonate or sulfate rocks for reasons discussed earlier. There is no evidence for significant occurrences of such lithologies in the stratigraphic succession within or underlying the Fraser Lowland.*
> 4. *There are no documented occurrences (to my knowledge) of non-biogenic H_2S encountered during exploration in the Fraser Lowland. Hydrogen sulphide, because of its smell and extreme toxicity, would not have been overlooked during exploration. One gas analysis made from a sample obtained at a well head from an improperly completed well in Boundary Bay yielded no trace of H_2S.*

Dr. Bustin further concluded:[22]

> *Based on the evidence at hand, there is a very low probability of significant H_2S being associated with any pooled hydrocarbons in the Fraser Lowland. This interpretation is based on the type of organic matter present, the low level of organic maturation of the potential source rocks and the absence of significant carbonate or evaporite deposits.*
>
> *Based on the low level of organic maturation of source rocks there is no evidence to suspect the presence of unusual quantities of CO_2 in any reservoired gas in the Fraser Lowland.*

John MacRae also stated that he has no information to indicate the presence of H_2S in the Fraser Valley. Before the technical hearings of the commission, MacRae stated:[23]

> *I would like to also briefly mention the fact that geochemical analyses have been conducted on a number of Georgia Basin surface and subsurface rock samples. The point of doing these analyses was to determine the potential for the generation of hydrocarbons from basin rocks.*
>
> *The results of these analyses indicate that although samples generally contain rather low percentages of hydrocarbon-generating organic material, the type of organic material encountered would generate dry, sweet — in other words, non-sour — natural gas, if present in sufficient quantities in the subsurface.*
>
> *Furthermore, the analysis just alluded to indicated that although the degree of organic maturation or, if I may be colloquial, the cooking of the sediment, although that varied, the range of observed measured maturation values encompassed those*

[21] Exhibit T-34, pages 16, 17.
[22] Exhibit, T-34, pages 18-19.
[23] Transcript, pages 89-90.

> *required for the generation of natural gas . . .*
>
> *I might add that the same geochemical analyses did not indicate a preponderance of oil generating sediments. The source rocks would appear to be far and away the sort of rock that would generate natural gas as opposed to liquid hydrocarbons. Obviously I say that within the constraints of the samples that have been measured.*

The commission has concluded that while the presence of hydrogen sulphide and sour gas may exist in the Fraser Valley, the possibility of encountering such gas is remote.

Drilling History

British Columbia

British Columbia has a long and extensive history of oil and gas exploration. The first exploratory wells were drilled in the late 1880s, in the Fernie-Flathead region in the southeastern corner of the province. Since then, some 7,000 wells have been drilled, primarily in the Peace River region of northeastern British Columbia, which is the only area of the province producing commercial quantities of oil and gas.

Following the drilling activity in southeastern British Columbia, the next area to be explored was the Fraser Valley in the early 1900s. The first recorded drilling records in the Fraser Valley date back to 1904. More activity took place between 1911 and 1918. Early drilling efforts in both the Flathead and Fraser Valley regions failed to discover significant quantities of oil or gas, although it has been reported that Steveston used Fraser Valley gas for street lights, and that a hospital in Delta used local natural gas for approximately six years.

British Columbia's first major oil and gas discovery occurred in 1922 at Pouce Coupe, in the Peace River region. This discovery was made in a large oil and gas deposit known as the Western Canada Sedimentary Basin.

The first gas producing well in British Columbia was established many years later in 1948. This well was named Peace River Natural Gas #1.

In 1956, large reserves of natural gas of similar geological age to those of the Leduc discovery in Alberta were discovered at Clarke Lake in the Peace River. These discoveries led to the decision to build the 1000 kilometre Westcoast Transmission Pipeline from the northeast to the southwest corner of the province, specifically to the U.S. border at Huntingdon, B.C. This pipeline was completed in 1958. The pipeline was expanded in 1971 to include natural gas discoveries at Beaver River and Pointed Mountain, near the border of the Northwest Territories. Currently there are more than 12,000 kilometres of gas gathering and distribution lines in B.C., operated by several pipeline companies.

Oil and gas production represents a major sector of the provincial economy, with an annual production value of approximately $800 million. British Columbia's oil production accounts for approximately one quarter of the province's needs, while gas production exceeds the province's needs and provides exports to Washington, Oregon and California.

Peace River

Drilling in British Columbia is currently concentrated geographically in the Peace River area. The Peace River is the only area in the province that produces significant quantities of natural gas. The B.C. foothills of the Rocky Mountains hold promise for natural gas reserve additions, and this area is increasingly becoming the focus of exploration activities.

In addition to the established gas producing region of the northeast, British Columbia also contains another four general frontier areas for oil and gas development.

Southeastern B.C.

The southeast of the province was the first area of drilling activity. Although no commercial quantities of oil and gas have been discovered, data indicate significant gas reserve potential. Approximately 40 wells have been drilled in this region since the 1880s, and interest in oil and gas drilling continues today.

Central Interior

The Central Interior region is a second oil and gas frontier in British Columbia It is home to the Nechako, Quesnel and Bowser sedimentary basins. The area has the potential for dry natural gas reserves, but the presence of gas in these basins is difficult to determine, due to complex geology and a lack of good geological data. Work by the Geological Survey of Canada is currently underway to expand the geological database for the region.

The Coast

The coast is considered another oil and gas frontier area. In recent years drilling has taken place both on Vancouver Island and on the Queen Charlotte Islands. A total of 53 wells have been drilled along the coast in the past century, but only 13 of these wells were drilled to depths in excess of 1000 metres. To date, onshore drilling along the coast has not led to the discovery of oil and gas in commercial quantities. However, the area is considered to possess many of the characteristics that indicate the possibility of oil and gas.

Offshore

The offshore area is the final general frontier area of the province. The offshore has been closed to petroleum exploration since 1972, when a federal moratorium on drilling activity was instituted. More recently in 1989, British Columbia placed its own moratorium on offshore drilling along its coast. The offshore contains two significant exploratory areas in the Tofino and Queen Charlotte Basins, and together these basins cover an area similar in size to the North Sea. Although existing geological data indicate the potential for significant oil and gas reserves, offshore drilling has many more environmental considerations to take into account than does onshore drilling.

British Columbia has had extensive experience with oil and gas drilling. Drilling for oil and gas in the province continues today. Since the late 1970s approximately 200 wells have been drilled in the province each year. Approximately 40% of the 7,000 wells in the province have turned out to be dry wells, 30% are gas wells, while 20% are oil wells. Another 7% of the wells drilled are used for servicing purposes.

The Fraser Valley

History

As discussed previously, oil and gas drilling in the Fraser Valley dates back to 1904. This oil and gas activity was in fact preceded by exploratory drilling for coal seams in the Fraser River Delta in the 1880s. Between 1911 and 1918, more extensive drilling occurred in the Fraser Valley area. These early years of exploratory activity represented the first wave of the search for oil and gas in the Fraser Valley.

The second wave of drilling in the Fraser Valley took place in the early to late 1950s. This led to the drilling of such wells as Royal Can Van-Tor Kuhn #1 to 1,585 metres and Hercon Key Evans #1 to 2,397 metres. These wells identified the presence of porous, water bearing sandstone with high porosity values (18-24%) at various underground depths. These records also indicated the possibility of natural gas in subsurface sandstone zones.

A significant amount of geological data collection was also carried out in the 1950s. Geologist Peter Gordy states that the earliest reported geophysical surveys aimed at petroleum exploration in the

Fraser Valley were carried out in 1959. Petcal Company Limited performed a gravity metre survey in this year which covered most of the Lower Fraser Valley River east of Abbotsford. The map showed several gravity minimas and maximas which were interpreted by the operator to reflect basement topography. The depth to basement, reflected by the gravity minimum centred on Sea Island, was estimated between 3,660 and 4,570 metres. Gordy cautions the use of these data, however, because of the imprecisely known thickness and distribution of unconsolidated sediments in the area. Gordy believes the gravity minimum at Sea Island may reflect the sediments of the modern Fraser River delta and an unknown thickness of glacial sediment.

Richfield Oil Corporation also conducted a fairly extensive seismic reflection survey in 1959, extending from Abbotsford to the U.S. border to the Strait of Georgia. Gordy states, however, that the techniques used make reliable interpretations of the data very difficult.

The early 1960s saw the third wave of drilling activity in the Fraser Valley. In 1962, Richfield Oil drilled three wells in Point Roberts, Sunnyside and Abbotsford. The Richfield Pure Abbotsford well was drilled to 958 metres, and encountered a relatively thin sedimentary rock sequence characterized by a lack of reservoir rock types.

The Richfield Pure Sunnyside well was drilled to 3,348 metres at a location northeast of White Rock. This well penetrated many sandstones with high porosity, but geological and engineering records provided no evidence of the presence of significant quantities of hydrocarbons.

The Richfield Pure Point Roberts well was drilled to a depth of 4,509 metres at a location southeast of the Tsawwassen ferry terminal near the Canada-U.S. border. This is the deepest well in the Fraser Valley and the deepest well in the province. Sandstones with high porosity were encountered at various depths, and several of these had the potential of being gas bearing.

No further exploratory drilling has been conducted in the Lower Fraser River Valley since the Richfield wells of 1962. In total, approximately 50 well sites have been documented in the Fraser Valley. The majority of these have been shallow wells (less than 300 metres). Only fifteen wells have been drilled to depths greater than 610 metres. Four of these were drilled deeper than 1,830 metres, and two were drilled to depths greater than 3,050 metres.

B.C. Hydro's Storage Proposal in Surrey

Between 1974 and 1979, B.C. Hydro investigated the potential for underground natural gas storage in the Fraser Valley, and specifically South Surrey. This resulted in the purchase of pre-existing geophysical data and the acquisition of new seismic data for the area. These data indicated the possible presence of several subsurface geological structures with gas storage potential. The proposal to store natural gas in South Surrey was rejected in July, 1979 by then B.C. Minister of Energy, Mines and Petroleum Resources, James Hewitt. The reason provided for the rejection of the proposal was that an underground storage facility would be in conflict with the development of a commercial-residential complex owned by Genstar Development Corporation. A secondary factor was that EMPR did not share B.C. Hydro's optimism regarding the potential for growth of the domestic gas market.

Current Work in the Fraser Valley

Most recently, in the late 1980s, geophysical information for the Fraser Valley was collected by both the petroleum industry and by the federal-provincial Lithoprobe project. The information acquired during this period included both seismic and gravity data. In October, 1989, federal geoscientists also conducted an extensive geophysical survey from northern Georgia Strait to Puget Sound.

Currently, geological studies in the Fraser Valley are being conducted by the Geological Survey of Canada in consultation with provincial geoscientists and British Columbia's universities, under the Frontier Geoscience Program (Georgia Basin Project). The aims of this project are to investigate the geological framework, hydrocarbon potential and geohazards potential of the region.

Although natural gas reserves in the Fraser Valley have not been adequately determined, a significant amount of geological and geophysical data have been accumulated through industry exploration activity and federal and provincial geological research.

Prospects

These data suggest that the Fraser Valley and other portions of the Georgia Basin have several key elements required for the formation of natural gas reservoirs. These include the basic requirements for adequate hydrocarbon source rocks and reservoir rocks, and geological trapping conditions.

In its technical submission to the commission, the B.C. Ministry of Energy, Mines and Petroleum Resources summarized its conclusions with respect to the potential for natural gas development in the Fraser Valley:[24]

> *Sandstone zones of excellent reservoir quality have been encountered; geochemical analyses indicate the potential for generation of dry, sweet gas from basin source sediments; and geophysical and surface structural data indicate the potential for encountering structural and stratigraphic traps in the subsurface.*
>
> *A fourth fundamental requirement for a hydrocarbon reservoir — the presence of impermeable layers of caprocks (reservoir seals) has not been extensively documented. However it is expected that the occurrence of alternating subsurface layers of sandstone, shale and siltstone provide opportunities for adequate caprock development.*

Geologist Peter Gordy also described significant potential for natural gas development in the Fraser Valley area in his 1988 report:[25]

> *The potential for hydrocarbon accumulation and gas storage sites in the Georgia Basin is in my opinion very good. The Fraser Lowland (Whatcom Basin) has many of the required ingredients to become an important hydrocarbon producing area.*

Vancouver Island

Exploration in the Vancouver Island area has consisted of three shallow test wells and five significant seismic surveys in the Strait of Georgia. Onshore exploration has consisted of significant amounts of surface mapping and stratigraphic descriptions in the 1950s and 1960s. Charter Oils drilled Saturna No. 1 on the Trincomali Anticline, which extends many kilometres through the Gulf Islands. The well spudded in the fall of 1957 and was abandoned in 1958 at a depth of 1,203 metres without encountering any significant reservoir. More recently in 1984 and 1985, British Petroleum conducted seismic surveys to the north and south of the Nanaimo area.

In June 1986, BP Canada and two B.C. firms, Cassidy Resources Ltd. and Laurel Explorations Ltd., began a $2.5 million gas drilling program near Nanaimo. The program consisted of drilling two wells in Cedar, a rural agricultural area south of Nanaimo. The first well was the Laurel Harmac well, which was drilled to a depth of 1,400 metres. The second well was the Laurel Yellow Point well, drilled to 1,574 metres. Neither well produced signs of oil or gas reserves, and the program was halted at the end of August 1986.

[24] Exhibit T-1, sec 3, page 16.
[25] Exhibit T-1-11, page 20.

Washington State

Like British Columbia, Washington State also has a long history of oil and gas exploration. Washington State has had some commercial production of oil and gas over the years, but the state has never encountered a large oil and gas discovery such as the one in the Peace River area of British Columbia.

Approximately 500 wells have been drilled in Washington for the purposes of oil and gas exploration. The most significant areas of drilling activity have been Rattlesnake Hills in the Columbia Basin, the Ocean City Field in Grays Harbor County, the Forks-Hoh River area in Challam and Jefferson counties, the Puget Lowland area, and Whatcom County in the Georgia Basin. Washington also has an underground gas storage facility in Jackson Prairie in western Lewis County.

Rattlesnake Hills is a gas field that was first discovered in 1913. The area produced nearly 1.3 billion cubic feet of gas between 1929 and 1941 when production ceased. This is the only site in Washington that has produced gas or oil in commercial quantities.

Of particular interest to the commission are drilling activities in Whatcom County, adjacent to the Canada-U.S. border, as well as the Jackson Prairie underground storage facility.

Whatcom County is part of the same geological structure as the Fraser Valley (lower Georgia depression). Approximately 100 wells have been drilled in Whatcom County since the beginning of the century, but none have identified the presence of a major reservoir. Fifteen of these wells have been drilled to depths greater than 610 metres, six of these were deeper than 1,525 metres, while the deepest well drilled was 2,900 metres. This deep well, named the American Hunter Birch Bay #1 well, was drilled at Birch Bay south of Blaine in 1988, and was subsequently abandoned. Geologist Peter Gordy indicates that some of the wells drilled south and east of Bellingham appeared to be located on surface anticlinal features. However, for the remainder of wells drilled in the county, technical data are not available.

In western Whatcom county, about 5 miles northwest of Bellingham, gas in sufficient quantity for domestic use has been obtained from glacial sediments at depths less than 150 metres, and commonly at about 50 metres.

Washington also contains a major gas storage facility in Jackson Prairie, 9 miles southeast of the city of Chehalis in western Lewis County. The project was started in 1963 by Washington Natural Gas Co. for the storage of natural gas from out of state. The reservoir rock for the Jackson Prairie project is the Skookamchuk Formation (late Eocene). There are 76 injection/withdrawal wells on the site, which has a storage capacity of 26 billion cubic feet.

No recommendations from Chapters 1 and 2.

From Chapter 3:

Recommendation 1

Minimum Technical Standard for Underground Storage Areas

That a minimum technical standard be added to Part 13.1 of the *Petroleum and Natural Gas Act* to require that underground storage facilities be permitted only in impervious strata which will effectively confine the stored gas, or other hydrocarbon.

Recommendation 2

Adoption of CSA Task Force Technical Standards

That should the 1989 recommendations of the CSA Task Force on Underground Storage of Hydrocarbons result in the production of a national technical standard for underground storage areas, such a standard, or selected parts of it, be incorporated in the *Drilling and Production Regulation* or the Ministry's Procedural Handbook.

Recommendation 3

Reporting Requirements — Underground Storage Areas

That a new Division (42A) of the *Drilling and Production Regulation* be enacted, setting out the reporting requirements for operators of underground storage areas.

Recommendation 4

Tracers Used Only With Approval

That the *Drilling and Production Regulation*, in a new Division (36A), require tracers be used only with written approval of the division head or an officer of the division.

Recommendation 5

Use of Tracers May Be Ordered

That the *Drilling and Production Regulation* provide that the division head may order the use of tracers in an underground storage area to assist in establishing or eliminating an underground storage area as a source of gas.

Recommendation 6

Acquisition of Other Interests in Non-Recoverable Hydrocarbon Deposits

That a legislative structure be established to provide for the fair and timely condemnation of third party interests in commercially non-recoverable original gas and for compensation for that condemnation.

From Chapter 4:

Recommendation 7

Storage Facility Depths

That any underground natural gas storage facility established in the Fraser Valley be at depths which provide at least one impermeable strata above the gas storage zone to act as a catchment area in case of gas migration.

Recommendation 8

Enactment of a Uniform Groundwater Conservation Act

That a single groundwater conservation statute be enacted and related regulations be drawn up. Such a statute would address water quality standards, aquifer classification, the regulation of both point and non-point sources of pollution, and related administrative procedures.

Recommendation 9

Toxic Soil

That toxic soil legislation based on the proposals contained in *Law Reform for Sustainable Development* of the British Columbia Branch of the Canadian Bar Association be enacted.

Recommendation 10

Declaration of Policy of Balanced Approach to Protection of the Province's Waters

That a policy of balanced protection of the Province's waters be established by means of a preamble to the *Groundwater Conservation Act* described in Recommendation 8, the *Environment Management Act*, and other appropriate statutes. The preamble might be in the following form:

> *The purpose of this Act is to ensure the purity of all waters of the Province consistent with public health and public enjoyment thereof, the propagation and protection of wildlife, birds, game, fish and other aquatic life, and the industrial development of the Province, and to that end require the use of all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the Province.*

Recommendation 11

Environmental Management Plan for Water Resources in the Fraser Valley

That in the event that the Recommendation above is not adopted, the Minister of Environment, under the *Environment Management Act*, s. 2(f)(iv), issue an environmental management plan for water resource management in the Fraser Valley, specifically to address the issue of petroleum and natural gas drilling.

Recommendation 12

Division Responsibility to Remedy Defective Old Abandoned Wells

That the *Petroleum and Natural Gas Act* and the *Drilling and Production Regulation* be amended to give the division the responsibility, authority and power to plug, replug, clean, or otherwise repair old test holes and petroleum exploration wells, and water wells, that appear to be a source or potential source of pollution, and that such a program be undertaken on a priority basis.

Recommendation 13

Underground Injection Control Program

That an underground injection control program be implemented, classifying wells and groundwater aquifers according to their purpose and identifying the substances that may be injected into them.

From Chapter 5:

Recommendation 14

Liquefaction Risk Assessment

That liquefaction-related earthquake risks to existing pipelines and other energy facilities in the Fraser Valley be assessed.

From Chapter 6:

Recommendation 15

Emergency Response Plan

That an emergency response plan for a drilling rig accident in the Fraser Valley initially should be for the very limited purpose of clearing an area near the rig of people. Subsidiary objectives, particularly subsidiary objectives that may require large numbers of people to be in the area for a long period of time, will make the plan less effective for this primary purpose, and should not be included.

Recommendation 16

Exclusion of Animals in Emergency Response Plan

That the evacuation of domestic and farm animals not be included as part of the emergency response plan of the Fraser Valley Gas Project consortium.

Recommendation 17

Anti-Crime Security Standards

That anti-crime security standards be set for petroleum and natural gas installations.

Recommendation 18

Security Survey Requirement

That s. 105 of the *Petroleum and Natural Gas Act* be amended to require the preparation and submission of a security survey with rig licence applications. The licence would be issued on the condition that the appropriate security recommendations in the survey be met.

From Chapter 7:

Recommendation 19

Endangered Species Habitat Protection

That a protection plan for river habitat of the Salish Sucker be developed by the Habitat Management Division of the Fisheries Branch of Environment BC.

Recommendation 20

Endangered Species Legislation

That endangered species protection legislation, modelled on the Ontario *Endangered Species Act*, be introduced in British Columbia.

From Chapter 8:

Recommendation 21

General Regulatory Approach to Noise Abatement

That in the application of noise abatement regulations and bylaws, petroleum exploration activities should be treated no differently than other industrial activities.

Recommendation 22

Method of Noise Measurement

That noise levels be measured with approved equipment, by properly trained and qualified personnel, both at standard distances from the noise-generating source, and at the windows of neighbouring residences.

Recommendation 23

***Environment Management Act* Noise Bylaws**

That the *Environment Management Act* be amended to make provision for municipal noise bylaws similar to those contemplated by the Ontario *Environmental Protection Act*.

Recommendation 24

Model Noise Bylaw

That the Ministry of Environment prepare a model noise bylaw for adoption by municipalities.

Recommendation 25

Noise Suppression Standard

That the Fraser Valley Gas Project Consortium adopt the more rigorous of the noise suppression standards discussed in its Summation to the Commission of November 1990, at page 20.

Recommendation 26

Negotiation of Compensatory Payments for Road Damage With Assistance of Mediation and Arbitration Board

That direct negotiation of "wear and tear" compensation payments to road maintenance authorities by petroleum industry road users moving oversize loads. This negotiation to be facilitated by expanding the role of the Mediation and Arbitration Board established by the *Petroleum and Natural Gas Act*.

No recommendations from Chapter 9.

From Chapter 10:

Recommendation 27

Captive Insurance Company

That if the government allows exploratory drilling to proceed, the Fraser Valley Gas Project is to establish a B.C. Captive Insurance Company, to be owned and financed by the Fraser Valley Gas Project, to provide insurance coverage for groundwater loss or other environmental damage to surface property owners.

Recommendation 28

Reverse Onus Clause re: Contamination of Water Sources Near Petroleum and Natural Gas Operations

That a reverse onus clause be enacted in the *Petroleum and Natural Gas Act* or other suitable provincial statute with respect to proving causation in groundwater contamination cases, reallocating the initial onus to the operator and/or owner of the exploration, drilling, production or gas storage operation.

Recommendation 29

Duty of Polluter to Restore or Replace Adversely Affected Water Supply

That legislation be enacted, setting out in detail the remedial action that may be required of persons who are found liable for damaging water supplies.

Recommendation 30

Alternative Dispute Resolution (ADR) Mechanism

That the function of the Mediation and Arbitration Board be expanded to include the mediation of disputes which would otherwise give rise to a tort action.

Recommendation 31

Enactment of Ontario-Type "Spills Bill"

That consideration be given to the enactment of legislation similar to the Ontario "Spills Bill." Such legislation could be enacted either as a replacement of ss. 123-25 of the B.C. *Petroleum and Natural Gas Act* or as a separate Act to deal with sources of pollution generally in the Province.

Recommendation 32

Creation of Environmental Compensation Board

That if Recommendation 31 is adopted, an Environmental Compensation Board be created, structured and funded in a manner similar to that created by the Ontario "Spills Bill."

From Chapter 11:

Recommendation 33

Minimum Distance Requirements

That no exception be made to existing minimum distance requirements for Fraser Valley drilling.

Recommendation 34

Well Spacing

That no exception be made to existing well spacing requirements for Fraser Valley drilling.

Recommendation 35

Best Engineering Practice

That present flexibility in the Act and Regulation to allow spacing based on Best Engineering Practice (BEP) to substitute for spacing based on horizontal distance be preserved.

Recommendation 36

Distinction Between Test Holes and Wells

That the distinction between test holes and wells in the *Petroleum and Natural Gas Act* be abolished.

Recommendation 37

Drilling Near a Permanent Building, Structure or Works

That the reference that no drilling shall occur within 80 metres of a "permanent building, structure or works" in the *Drilling and Production Regulation* be

redrafted to provide that the requirement pertain only to buildings occupied by persons or domestic animals.

Recommendation 38

Discretionary Powers of Officers of the Division

That the discretionary powers in ss. 9.01 and 10.01 of the *Drilling and Production Regulation*, whereby an officer of the division can give written permission for a well to be drilled at a specified position notwithstanding the Regulation, be maintained.

From Chapter 12:

Recommendation 39

Statement of Purpose in Each Division of Drilling and Production Regulation

That each Division of the *Drilling and Production Regulation* commence, where applicable, with a statement of the purpose or goal of that Division.

Recommendation 40

Regulations Not to be Excessively Specific

That in prescribing specific equipment, procedures and other technological requirements in a regulation, sufficient flexibility be maintained to ensure that the most advanced procedures, or procedures most appropriate for particular circumstances, can be used by the operator.

Recommendation 41

Regular Review of Regulations if Highly Specific

That if the Recommendation above is not followed, regulations be reviewed regularly, perhaps on an ongoing basis, to ensure that they reflect current advances in drilling technology.

Recommendation 42

Preserving Division's Discretion to Set More Stringent Standard Than Regulations Provide

That the discretion of the Minister, division head and officers of the division to set procedures and fix standards of equipment, notwithstanding the regulations, be preserved.

Recommendation 43

Forms of Security to be Provided by Operators

That Part (21) of the *Drilling and Production Regulation* be amended, to give the Minister the discretion to determine the amount and type of security to be provided.

Recommendation 44

Extension of Minister's Power to Take Over Non-Complying Wells

That the Minister be empowered to take over non-complying wells which are not necessarily an imminent hazard, but where there are violations not remedied after notice. The powers would include: plugging the well or taking action necessary to bring it into compliance, and sale of salvage or of the well itself to cover expenses incurred by the Ministry. The amendment would also provide for forfeiture of any deposit or bond, to cover expenses, as well as a cause of action for any deficiency not covered by the Minister's other remedies.

Recommendation 45

Raising Maximum Fines Generally

That s. 142 of the *Petroleum and Natural Gas Act* be amended to provide for a higher maximum fine than that currently available, for any offence under the Act or Regulation.

Recommendation 46

Minimum Fine

That the minimum fine should be left at its current level of $500.

Recommendation 47

No Distinction Between Maximum Fines for Corporations and Individuals

That a relatively high maximum fine be set for both individuals and corporations, thus maximizing the discretion of the courts to set fines appropriate to all the circumstances of a particular case.

Recommendation 48

Forfeiture

That s. 142 of the *Petroleum and Natural Gas Act* be amended to provide forfeiture provisions as a sentencing option. Such a provision might follow the form of the draft statute in Recommendation 44.

Recommendation 49

Suspension or Cancellation of Permits, Licences and Leases

That s. 142 of the *Petroleum and Natural Gas Act* be amended to confer upon the courts the option in sentencing of cancelling or suspending a permit, licence or lease where there has been a violation of the Act or Regulation.

Recommendation 50

Imprisonment of Corporate Officers and Employees

That s. 142(1) of the *Petroleum and Natural Gas Act* be amended to bring it into conformity with the *Waste Management Act*, particularly subsection 16 of section 34, to provide for terms of imprisonment in lieu of or in addition to any fine levied.

Recommendation 51

Administrative Penalties

That administrators of the *Petroleum and Natural Gas Act* be empowered to impose administrative penalties for breaches of the Act or Regulation, possibly modelled on the practice of the Workers' Compensation Board or on the legislation of Pennsylvania.

Recommendation 52

Clarification of Enforcement Power Under Drilling and Production Regulation

That s. 107.02 of the *Drilling and Production Regulation* be amended to read: "Where an officer of the division is authorized to issue an order or make a request under these regulations, the person to whom the order is issued or request made shall comply with the order or request."

From Chapter 13:

Recommendation 53

Communications Program

That in the event the government permits exploratory drilling, an effective communications program of the levels of risk that are posed by the drilling should take place.

Recommendation 54

Negotiation and Compensation

That in the event the government permits exploratory drilling, negotiation and compensation discussions with those who may be affected by the drilling should be undertaken.

Recommendation 55

Citizens Advisory Council

That in the event the government permits exploratory drilling, a Citizens Advisory Council be set up to provide advice on aesthetic and amenity issues related to the drilling.

From Chapter 14:

Recommendation 56

Expanded Use of Hearings

That hearings be held during the process of approval of petroleum exploration proposals.

Recommendation 57

Provision for Hearing Where Environmental Protection Order Under Consideration

That the *Environment Management Act*, ss. 4(3) and 4(5), be amended to provide for a hearing where the Minister of Environment or the Lieutenant Governor in Council is considering the issuance of an environmental protection order in respect of any existing or proposed petroleum and natural gas operation.

Recommendation 58

Intervenor Funding System

That where hearings are held, public input be facilitated through implementation of an intervenor funding program similar to the Ontario *Intervenor Funding Project Act, 1988*.

Recommendation 59

Private Citizen Conference Process to Negotiate Compliance With Statute and/or Regulations

That the *Petroleum and Natural Gas Act* be amended to provide for a conference process whereby private individuals affected by non-complying operations may seek a conference with Ministry officials and industry representatives, in an effort to negotiate compliance with the Act and regulations.

APPENDIX A

Commission on Fraser Valley Petroleum Exploration Terms of Reference

1. The Commissioner shall inquire into and report, prior to September 30, 1990 on all matters concerning exploration for and development of petroleum, natural gas or natural gas storage in the Fraser Valley, and the areas if any, that should be excluded from petroleum or natural gas exploration, development or storage by virtue of risk, land-use conflict or other factors and the conditions that should govern these exclusions.

2. Without limiting the generality of the foregoing, but as an aid to the Inquiry, the Commissioner is directed to enquire into, investigate, review and report on:
   (a) the geological, environmental, land-use and socio-economic characteristics of the Fraser Valley;
   (b) the proposed exploration program, together with subsequent exploration for and development of petroleum, natural gas or natural gas storage which might reasonably be expected from a discovery;
   (c) exploration, development and natural gas storage experience in other jurisdictions and areas of a similar nature;
   (d) possible risks to public health and safety, property and amenity values including potential groundwater contamination, noise and well control problems;
   (e) potential environmental and socio-economic impacts, including disturbance of land, wildlife and the natural environment;
   (f) existing regulations, practices and guidelines applicable to exploration, development or natural gas storage in the Fraser Valley;
   (g) the potential benefits of exploration or development to the Provincial economy, utilities, businesses and residents;
   (h) methods of avoiding, reducing or mitigating risk and impacts to acceptable levels, and of increasing the benefits to residents, the region and the Province, including suggested changes to regulatory practice necessary to ensure safe, prudent and environmentally acceptable activity, and the Commissioner should specifically review:
      (i) regulations applicable to natural gas storage;
      (ii) provisions of existing drilling liability deposits and other means of covering liability;
      (iii) the existing "minimum distance" and spacing regulations.

3. In this order, "Fraser Valley" means the area commencing at a point on the west coast of the Sechelt Peninsula at latitude 49°30'N, then east to longitude 121°30'W, then south to the Canada-United States of America boundary, then west along said boundary to the Strait of Georgia at longitude 123°07'30"W, then follow coast in general northwest direction to the point of commencement, excluding all marine areas below the high water mark.

APPENDIX B

David Anderson

Biography

Born in Victoria in 1937, David Anderson, is a graduate of the University of British Columbia Law School, and the Institute of Oriental Studies of the University of Hong Kong.

During Mr. Anderson's four years as a Member of Parliament for Esquimalt Saanich from 1968 to 1972, he founded the House of Commons Committee on Environmental Pollution, and was elected as its first chairman. In this period he became widely known on both sides of the US/Canadian border for his opposition to the proposed TransAlaska Pipeline System, a battle which involved a successful four year lawsuit in the American courts under the provisions of the Environmental Policy Act against the United States' Secretary of the Interior.

From 1976 to 1979, Mr. Anderson worked with the British Columbia Wildlife Federation on various oil port and pipeline proposals on the West Coast, principally as counsel before the National Energy Board, the West Coast Oil Ports Inquiry, and the Washington State Energy Facilities Site Evaluation Council. During this period he also did consulting work on environmental and constitutional law for Environment Canada. In 1979 he joined the faculty of the School of Public Administration of the University of Victoria, where he taught constitutional and administrative law, and also taught in the Environmental Studies Program.

In 1989, following the Nestucca and the Exxon Valdez spills, Mr. Anderson was asked to serve as a special advisor to the Premier of B.C. on tanker traffic and oil spills. His report was presented in November of that year, and has formed the basis of recent improvements in the safety of tanker traffic in B.C. waters.

In May of 1990 he was asked by the Honourable Jack Davis, the Minister of Energy, Mines and Petroleum Resources, to be a sole commissioner under part two of the *Inquiry Act* to examine the question of Fraser Valley petroleum exploration, and to report on possible environmental, socio-economic, and other effects.

Mr. Anderson is a member of the Sierra Club, the Audubon Society, the Steelhead Society, Ducks Unlimited, a life member of the British Columbia Wildlife Federation, and an honourary director of the West Coast Environmental Law Association. He is a convocation senator of the University of British Columbia Senate. In 1990 his environmental work and public service was recognized by his selection by the Alumni Association as one of UBC's 75 distinguished graduates.

Mr. Anderson lives in Victoria with his wife Sandra McCallum, and their two children aged seven and three.

APPENDIX C

Commissioner's Statements, Public Advisory Notices and News Releases

Commissioner's Statements:

31 May 1990	— Invitation to the public to attend the initial public information session on 12 June 1990. Those interested in making statements, submitting evidence or being placed on the commission mailing list are asked to contact the commission office in Langley.
4 June 1990	— Letters to community groups inviting their participation in the inquiry process.
12 June 1990	— Opening remarks of the Commissioner regarding rules and timetable of the commission.
13 June 1990	— Letters to mailing list outlining rules and timetable of commission.
29 June 1990	— Letters to mailing list indicating dates and locations of two weeks of technical hearings.
6 July 1990	— Letters to mailing list indicating availablity of commission research library in Langley.
10 August 1990	— Letters to mailing list outlining technical hearings and tentative list of witnesses, and subjects to be discussed.
27 August 1990	— Opening remarks of the Commissioner at the technical hearings.
5 October 1990	— Letters to mailing list requesting assistance for the commission's investigation into allegations made by the Friends of the Fraser Valley.

Public Advisory Notices:

June-July 1990	— Public Meeting Notices — advertisements placed in local and major newspapers.
August-September 1990	— Technical Hearing Notices — advertisements placed in local and major newspapers.
October 1990	— Special Hearing Notice — advertisements placed in local and major newspapers.

Commission News Releases:

5 September 1990	— Response to the Friends of the Fraser Valley's decision to withdraw from the inquiry process.
21 September 1990	— Request to the public to assist the commission's investigation of allegations made by the Friends of the Fraser Valley that potential witnesses were pressured into remaining silent.
25 September 1990	— Response to the Friends of the Fraser Valley regarding procedures adopted by the commission.
27 November 1990	— Statement accompanying release of Special Report into Allegations of Witness Tampering at the Commission Hearings, and findings that no potential witnesses were pressured or that untruthful evidence was presented.

APPENDIX D

List of Inquiry Public Meetings

An initial public information session was held June 12, 1990 at the Kinsmen Community Centre in Aldergrove. The purpose of this session was for the Fraser Valley Gas Project to outline its proposed program. This session was followed by nine public meetings over the next month, where the public had an opportunity to participate. These meetings were held at the following locations and dates:

1. **Abbotsford/Clearbrook Public Meeting, June 18, 1990**
   Ag. Rec. Building
   Central Fraser Valley Exhibition Park
   Tretheway & Maclure Street
   Clearbrook
2. **Cloverdale/Surrey Public Meeting, June 19, 1990**
   Community Centre Boardroom
   Cloverdale Fairgrounds
   6050-176th Street
   Cloverdale
3. **Langley Public Meeting, June 25, 1990**
   The Langley Conference Centre
   20381-66th Avenue
   Langley
4. **Tsawwassen/Delta Public Meeting, June 26, 1990**
   Town & Country Inn
   Junction of Highway 17 & 99
   Delta
5. **Maple Ridge Public Meeting, July 3, 1990**
   The Old Library Auditorium
   11963 Haney Place
   Maple Ridge
6. **White Rock Public Meeting, July 4, 1990**
   The Upper Town Centre Hall
   15150 Russell Avenue
   White Rock
7. **Chilliwack Public Meeting, July 9, 1990**
   Best Western Rainbow Country Inn
   43971 Industrial Way
   Chilliwack
8. **Mission Public Meeting, July 10, 1990**
   The Mission Leisure Centre
   7621 Taulbut Street
   Mission
9. **Aldergrove Public Meeting, July 11, 1990**
   Kinsmen Community Centre
   26770 29th Avenue
   Aldergrove

* *All meetings commenced at 7:30 p.m.*

APPENDIX E

List of Technical Hearings, Witnesses and Subjects Discussed

Sixteen technical hearings took place between August 27 and September 6, 1990. In the week of August 27-31, technical hearings were held at the Town & Country Inn, Junction of Highway 17 and 19, Delta. In the week of September 4-6, technical hearings were held at the Langley Conference Centre, 20381-66th Avenue, Langley.

Technical Hearing 1, August 27, 1990

Witnesses:

Dave Johnson, Ministry of Energy, Mines and Petroleum Resources
Bruce Hanwell, Ministry of Energy, Mines and Petroleum Resources
Gerald German, Ministry of Energy, Mines and Petroleum Resources
John MacRae, Ministry of Energy, Mines and Petroleum Resources
Bou van Oort, Ministry of Energy, Mines and Petroleum Resources
Joan Hesketh, Ministry of Energy, Mines and Petroleum Resources
Rebecca Vermeer, Ministry of Energy, Mines and Petroleum Resources
Ken Kindjerski, Ministry of Energy, Mines and Petroleum Resources

Subjects Discussed:

Ministry Overview
Petroleum Geology in British Columbia

Technical Hearing 2, August 27, 1990

Witnesses:

Gary Runka, G.G. Runka Land Sense Ltd.
Kirk Miller, Agricultural Land Commission

Subjects Discussed:

Land and Water Use Overview in the Fraser Valley

Technical Hearing 3, August 28, 1990

Witnesses:

John MacRae, Ministry of Energy, Mines and Petroleum Resources
Dave Johnson, Ministry of Energy, Mines and Petroleum Resources
Bou van Oort, Ministry of Energy, Mines and Petroleum Resources
Gerald German, Ministry of Energy, Mines and Petroleum Resources
Bruce Hanwell, Ministry of Energy, Mines and Petroleum Resources
Harold Larson, Ministry of Energy, Mines and Petroleum Resources

Subjects Discussed:

Geology
Petroleum Title in British Columbia
Petroleum Engineering and Operations in British Columbia

Technical Hearing 4, August 28, 1990

Witnesses:
Dave Holowachuk, Conoco Canada Ltd.
Ed Nordquist, Conoco Canada Ltd.
Bob Spring, Conoco Canada Ltd.
Bruce Hanwell, Ministry of Energy, Mines and Petroleum Resources
Dave Johnson, Ministry of Energy, Mines and Petroleum Resources
Ken Kindjerski, Ministry of Energy, Mines and Petroleum Resources

Subjects Discussed:
Groundwater Protection
Drilling Methods Proposed by the Consortium

Technical Hearing 5, August 29, 1990

Witnesses:
Allan Dakin, Piteau Associates
Hugh Liebscher, Environment Canada
Al Kohut, Ministry of Environment

Subjects Discussed:
Groundwater and Hydrological Issues

Technical Hearing 6, August 29, 1990

Witnesses:
Dr. Dieter Weichert, Pacific Geoscience Centre
Dr. Liam Finn, Department of Engineering, University of British Columbia
Dr. Stephen Palmer, State of Washington

Subjects Discussed:
Seismological Risk and the Impact of Seismological Happenings on Petroleum Installations

Technical Hearing 7, August 30, 1990

Witness:
John Ahern, Legal Consultant

Subjects Discussed:
Regulatory and Statutory Frameworks Governing Exploration, Drilling, and Production of Hydrocarbons and Storage of Natural Gas

Technical Hearing 8, August 30, 1990

Witnesses:
Graham McCredie, United Resource Safety Ltd.
Bob Spring, Conoco Canada Ltd.
Ed Nordquist, Conoco Canada Ltd.
Dave Johnson, Conoco Canada Ltd.
Ken Kindjerski, Ministry of Energy, Mines and Petroleum Resources
Bruce Hanwell, Ministry of Energy, Mines and Petroleum Resources
Harold Larson, Ministry of Energy, Mines and Petroleum Resources

Subjects Discussed:
Emergency Response Plan

Technical Hearing 9, August 31, 1990

Witness:
Gary Ely, Washington Water Power Company

Subjects Discussed:
Underground Storage of Natural Gas- Economics
Role of Underground Storage in the Pacific Northwest

Technical Hearing 10, August 31, 1990

Witnesses:
John Nichol, Alberta Energy Resources Conservation Board
Emil Morin, Alberta Energy Resources Conservation Board

Subjects Discussed:
Sour Gas, Blowouts and Regulations for Safety

Technical Hearing 11, September 4, 1990

Witness:
Art Willms, Westcoast Energy Ltd.

Subjects Discussed:
Description of the Westcoast Gas Delivery System from the Peace River
Economics of Gas Transmission and the Role of Storage

Technical Hearing 12, September 4, 1990

Witnesses:
John Thrasher, BC Gas Inc.
Robert Stepan, BC Gas Inc.
Patrick Lloyd, BC Gas Inc.

Subjects Discussed:
Introduction to the Storage Proposal

Technnical Hearing 13, September 4, 1990

Witnesses:
Howard Griffith, TXG Consulting Ltd.
Paul Dubois, TXG Consulting Ltd.
Dr. Rasin Tek, University of Michigan

Subjects Discussed:
Underground Storage of Natural Gas
Problem Areas and Operating Requirements

Technical Hearing 14, September 5, 1990

Witnesses:
Ivan Cuthill, Tecumseh Gas Storage Ltd. and Consultant to Consumers Gas
Vince Grass, formerly with Jackson Prairie Storage Facility
Yannick Guerrini, Gaz de France

Subjects Discussed:
Underground Natural Gas Storage
Experience of Operators

Technical Hearing 15, September 5, 1990

Witnesses:
Mark Nida, State of Michigan
William Lingley, State of Washington
Bou van Oort, Ministry of Energy, Mines and Petroleum Resources
Bruce Hanwell, Ministry of Energy, Mines and Petroleum Resources

Subjects Discussed:
Regulations in Respect of Natural Gas Storage
Sour Gas, Blowouts, Regulations for Safety

Technical Hearing 16, September 6, 1990

Witnesses:
Robert Means, retired from the Gas Light and Coke Company
Douglas Ball, Ball and Associates Ltd.

Subjects Discussed:
Underground Natural Gas Storage
Safety, Operating Requirements and Possible Risks

APPENDIX F

List of Exhibits Received at Inquiry Technical Hearings

T-1 Ministry of Energy, Mines and Petroleum Resources Overview
Petroleum Title in British Columbia
Petroleum Geology in British Columbia
Petroleum Engineering and Operations in British Columbia
Technical Submission Summary
Related Publications — *in white 3-ring binder (complete in itself)* — EMPR

T-1-1 Business Plan — EMPR

T-1-2 Utilities Commission Act — EMPR

T-1-3 Table — BC Natural Gas Forecast — EMPR

T-1-4 Oil & Gas in BC — Statistics 1047-89 — EMPR

T-1-5 Bonus Revenues — EMPR

T-1-6 Wells Drilled — EMPR

T-1-7 BC Natural Gas Core Market Policy — EMPR

T-1-8 BC Utilities Commission — Rules for Review of Natural Gas Supply Contracts — EMPR

T-1-9 BC Natural Gas Removal Policy — EMPR

T-1-10 Guide to the Energy Project Review Process — EMPR

T-1-11 Evaluation of the Hydrocarbon Potential of the Georgia Depression — Peter L. Gordy, Consultant for EMPR, 1988.

T-2 Land and Water Use Overview — Gary Runka

T-3 Petroleum Titles Branch Exhibits — *in 3-ring binder (complete in itself)* — EMPR

T-4 Information letter — Public Consultation Guidelines Oil and Gas Development — EMPR

T-5 Hydrocarbon & By-Product Reserves in BC 1989 — EMPR

T-6 Land Act — Chapter 214 (Consolidated January 17, 1989) — EMPR

T-7 Information letter — Well Authorization Application Procedure — EMPR

T-8 Pipeline Act — Chapter 328 (Consolidated October 20, 1987) — EMPR

T-9 Petroleum & Natural Gas Act — Drilling & Production Regulation (Consolidated June 30, 1989) — EMPR

T-10 Petroleum & Natural Gas Act — Chapter 323 (Consolidated January 17, 1989) — EMPR

T-11 Electrical Safety Act — Chapter 104 (Consolidated October 20, 1987) — EMPR

T-12 Utilities Commission Act — Chapter 60 (Consolidated November 3, 1989) — EMPR

T-13 Water Act — Chapter 429 (Consolidated February 29, 1988) — EMPR

T-14 Waste Management Act — Chapter 41 (Consolidated November 3, 1989) — EMPR

T-15 Drilling & Production Procedural Handbook — EMPR

T-16 Protection of Groundwater — Conoco Canada Ltd.

T-17 Initial Environmental Investigation — EMPR

T-18 Letter of Referral for Access Routes and Wellsites on Crown Land — EMPR

T-19 Letter of Referral for Access Routes and Wellsites on Private Land — EMPR

T-20 Detailed Drilling Rig Inspection Report — EMPR

T-21 Detailed Service Rig Inspection Report — EMPR

T-22 Guidelines for Construction and Cleanup of Roads, Leases and Seismic Lines in Petroleum Exploration Areas — EMPR

T-23 Prevention of Groundwater Contamination — Presentation by Energy Resources Division/Engineering and Operations Branch — EMPR

T-24 Application for Production Facility — EMPR

T-25 Application for Well or Facility to Facility Linkage — EMPR

T-26 Potential Impacts on Groundwater Resources and Operations — Piteau Associates — Allan Dakin

T-27-1 Earthquakes — Testimony of Stephen P. Palmer

T-28 Seismic Risks Associated with Gas Field Development in the Fraser Valley — Pan American Engineering & Computing Services Ltd., Dr. Liam Finn

T-29 Performance of Natural Gas Storage and Production Field Facilities to Earthquakes — EQE Engineering

T-30 Regulation of Petroleum Exploration in the Fraser Valley: Options for Reform — Prepared by John N. Ahern

T-31 Addendum — Fisheries Act — John N. Ahern

T-32 Emergency Response Plan — Conoco Canada Ltd.

T-33 Emergency Responses Plan Requirements — EMPR

T-34 Potential for Hydrocarbons and Hydrogen Sulphide in the Fraser Lowland — R. M. Bustin, Phd

T-35 Summary of B. C. Gas Contractual Agreement for the Release of Jackson Prairie Storage Capacity — Gary G. Ely

T-36 Agreement Between B. C. Gas Inc. and the Washington Water Power Company — Gary G. Ely

T-37 Energy Resources Conservation Board of Alberta — J. R. Nichol, P. Eng

T-38 Energy Resources Conservation Board of Alberta — E. J. Morin, Board Member

T-39 The Effect of Sour Gas Facilities on Property Values in the Crossfield, Okotoks and Pincher Creek Regions of Alberta — Deloitte Haskins & Sells, Edmonton, Alberta — November, 1988

T-40 The Effect of Sour Gas Facilities on Land Values in West Central Alberta — Jim Lore & Associates Ltd., November 14, 1988

T-41 The Westcoast System — By Westcoast Energy Inc.

T-42 B. C. Gas Inc. — Presented by Patrick D. Lloyd — *B. C. Gas (green 3-ring binder — complete in itself) — Binder 7*

T-43 Peaking Supply Sources — B. C. Gas

T-44 Annual Gas Supply Curve (overheads) — B. C. Gas

T-45 B. C. Gas 1989 Sales — B. C. Gas

T-46 Storage — Testimony of Howard D. Griffith

T-47 Storage — Problems, Perspectives and Solutions on Development of Underground Storage Reservoirs — M. R. Tek, Professor Emeritus

T-48 Storage — Gas de France — Yannick Guerrini

T-49 Storage — Underground Storage an Essential Component of Ontario's Natural Gas Supply — ConGas Engineering Canada Ltd.

T-50 Washington Geologic Newsletter — Vince Grass

T-51 Storage — Testimony of Mark Nida

T-52 Recommended Environmental Review Procedures — State of Michigan — Mark Nida

T-53 An Analysis of the AMOCO State Whitewater 'E' 1-22 Well as the Cause of the Natural Gas Eruptions at Williamsburg and ACME, Michigan — Mark Nida

T-54 Isotopic Identification of Leakage Gas from Underground Storage Reservoirs — A Progress Report — Bill Lingley

T-55 Underground Gas Storage — EMPR

T- 56 Gas Storage in the United States (1971) — The Storage of Gas in Water Sands (Long Earlier Version) — The Storage of Gas in Water Sands (Short Later Version) — Ball Associates Ltd. — Douglas Ball

T-57 Summary — Aquifer Gas Storage — SITE SELECTION — Robert D. Means, Consultant

APPENDIX G

Commission Field Trips

1. **British Columbia**
   - (a) Three currently proposed wellsites, Delta and Langley
   - (b) Boundary Bay No. 3 Wellsite, previous drill site, south foot of 88th Street, Delta
   - (c) Laurel Harmac Wellsite, site of 1986 BP well, near Nanaimo
   - (d) Laurel Yellow Point Wellsite, site of 1986 BP well, near Nanaimo
   - (e) Aitken Creek Gas Storage Facility, Peace River
   - (f) Poco N. Pine 5-12-85-18 Well (deviated well), Peace River
   - (g) Trilogy Inga c-58-B/94-A-13 Well, Peace River

2. **Alberta**
   - (a) Pembina Oil Field, Drayton Valley
   - (b) Energy Resources Conservation Board, Calgary

3. **Ontario**
   - (a) Tecumseh Gas Storage Facility, Sarnia
   - (b) Consumers Gas, Toronto

4. **Washington**
   - (a) State Regulators, Olympia
   - (b) Jackson Prairie Gas Storage Facility, Chehalis

5. **Oregon**
   - (a) State Regulators, Salem
   - (b) State Regulators, Portland
   - (c) Mist Gas Storage Facility, Portland

6. **California**
   - (a) State Regulators, Longbeach
   - (b) Montebello Gas Storage Facility, Los Angeles
   - (c) Playa del Rey Gas Storage Facility, Los Angeles

7. **Michigan**
   - (a) State Regulators, Traverse City
   - (b) Kalkaska Gas Storage Facility, Traverse City
   - (c) Amoco State Whitewater "E" 1-22 Well, site of 1973 blowout at Willamsburg

8. **Illinois**
   - (a) State Regulators and Illinois Commerce Commission Representative, Springfield
   - (b) Ancona Gas Storage Facility, near Chicago

9. Kentucky

(a) TXG Engineering, Commission Counsel visit, Owensboro

10. Missouri

(a) Laclede Gas Storage Facility, St. Louis

11. France

(a) Gaz de France Research Centre, Beynes near Paris
(b) Gournay Sur Aronde Gas Storage Facility
(c) Chemery Gas Storage Facility
(d) Drilling Site, Soings-en-Sologne
(e) Beynes Gas Storage Facility

12. Italy

(a) Ripalta Gas Storage Facility, Milan
(b) Sergnano Gas Storage Facility

13. England

(a) Wytch Farm Production Facility, Poole, Dorset

APPENDIX H

Overview of the Petroleum and Natural Gas Tenure System in British Columbia

ACQUISITION

Petroleum and natural gas permits may be obtained in non-designated Crown Reserve areas by filing an application. Petroleum and natural gas rights in areas designated Crown Reserve may only be obtained through competitive bidding.

TYPES OF TENURE

Permits —

Issued for 1 year with 1 year renewals available with payment of annual fees, rental and the satisfaction of work requirements.

Allows for the exploration of petroleum and natural gas rights with up to 50% of area converted to leases at end of term.

Drilling Licences —

Issued for 3, 4 or 5 year terms with a 1 year extension available.

Allows for the exploration of petroleum and natural gas rights. May be converted to leases at any time. Amount of area to be leased determined by depth and number of wells drilled. Leases issued only to base of deepest formation penetrated.

Leases —

Issued for 5 or 10 year terms depending on geographic location (5 year terms in Lower Mainland area). Payment of annual rental required.

Allows for exclusive rights to explore, develop and produce petroleum and natural gas.

At end of initial term may be continued on year-to-year basis dependent on proven reserves of petroleum or natural gas.

If lease does not qualify for continuation on basis of proven reserves, it may be continued by lessee's commitment to perform other approved exploratory work.

Source: Ministry of Energy, Mines and Petroleum Resources, 1990.

APPENDIX I

Fraser Valley Titles

LEASES

1. **Lease 15837 — General Area: Delta**
   Issue Date: October 25, 1989
   Term: 5 years
   Acquisition: Sale PCL 12188
   Total Bonus Amount: $82,500.00
   Titleholders: Conoco Canada Limited — 100%
   Hectares: 264
   Annual Rental: $1,980.00

2. **Lease 15838 — General Area: Delta**
   Issue Date: October 25, 1989
   Term: 5 years
   Acquisition: Sale PCL 12189
   Total Bonus Amount: $331,005.78
   Titleholders: Conoco Canada Limited — 100%
   Hectares: 441
   Annual Rental: $3,307.50

3. **Lease 15839 — General Area: Surrey**
   Issue Date: October 25, 1989
   Term: 5 years
   Acquisition: Sale PCL 12190
   Total Bonus Amount: $60,394.88
   Titlesholders: Conoco Canada Limited — 100%
   Hectares: 476
   Annual Rental: $3,570.00

4. **Lease 15840 — General Area: Langley**
   Issue Date: October 25, 1989
   Term: 5 years
   Acquisition: Sale PCL 12195
   Total Bonus Amount: $20,479.13
   Titleholders: Conoco Canada Limited — 100%
   Hectares: 259
   Annual Rental: $1,942.50

5. **Lease 15841 — General Area: Langley**
   Issue Date: October 25, 1989
   Term: 5 years
   Acquisition: Sale PCL 12196
   Total Bonus Amount: $153,599.95
   Titleholders: Conoco Canada Limited — 100%
   Hectares: 259
   Annual Rental: $1,942.50

6. **Lease 15842 — General Area: Langley**
   Issue Date: October 25, 1989
   Term: 5 years
   Acquisition: Sale PCL 12197
   Total Bonus Amount: $153,599.95
   Titleholders: Conoco Canada Limited — 100%
   Hectares: 259
   Annual Rental: $1,942.50

DRILLING LICENCES

1. **Drilling Licence 448 — General Area: Aldergrove**
   Issue Date: October 25, 1989
   Term: 3 years
   Acquisition: Sale PCL 12158
   Total Bonus Amount: $1,100,016.72
   Titleholders: Conoco Canada Limited — 100%
   Hectares: 2,211
   Annual Rental: $5,527.50

2. **Drilling Licence 449 — General Area: Aldergrove**
   Issue Date: October 25, 1989
   Term: 3 years
   Acquisition: Sale PCL 12159
   Total Bonus Amount: $355,571.56
   Titleholders: B.C. Gas Inc. — 80%
   Canadian Hunter Exploration Ltd. — 10%
   Epic Resources B.C. Ltd. — 7.5%
   Optima Energy Corporation — 2.5%
   Hectares: 2,612
   Annual Rental: $6,530.00

3. **Drilling Licence 450 — General Area: Aldergrove**
   Issue Date: October 25, 1989
   Term: 3 years
   Acquisition: Sale PCL 12161
   Total Bonus Amount: $3,143,010.50
   Titleholders: Conoco Canada Limtied — 100%
   Hectares: 3,310
   Annual Rental: $8,275.00

4. **Drilling Licence 451 — General Area: Clearbrook**
   Issue Date: October 25, 1989
   Term: 3 years
   Acquisition: Sale PCL 12162
   Total Bonus Amount: $175,572.36
   Titleholders: Canadian Coastal Resources Ltd. — 100%
   Hectares: 2,007
   Annual Rental: $5,017.50

PERMITS

1. **Permit 3133 — Class "A" — General Area: Port Coquitlam**
   Issue Date: April 8, 1987
   Term: 1 year with 4 one year renewals; additional renewals may be approved by Minister (Maximum 7)
   Acquisition: Filing
   Total Bonus Amount: n/a
   Titleholders: Epic Resources B.C. Ltd. — 100%
   Hectares: 6,910
   Current Rental: $5,182.50

2. **Permit 3134 — Class "A" — General Area: Port Coquitlam**
   Issue Date: April 8, 1987
   Term: 1 year with 4 one year renewals; additional renewals may be approved by Minister (Maximum 7)
   Acquisition: Filing
   Total Bonus Amount: n/a
   Titleholders: Epic Resources B.C. Ltd. — 100%
   Hectares: 4,780
   Current Rental: $3,585.00

3. **Permit 3138 — Class "A" — General Area: Port Coquitlam**
   Issue Date: July 29, 1987
   Term: 1 year with 4 one year renewals; additional renewals may be approved by Minister (Maximum 7)
   Acquisition: Filing
   Total Bonus Amount: n/a
   Titleholders: Epic Resources B.C. Ltd. — 100%
   Hectares: 6,233
   Current Rental: $3,116.50
   Note: Cancelled July 29, 1990

4. **Permit 3139 — Class "A" — General Area: Mission**
   Issue Date: July 29, 1987
   Term: 1 year with 4 one year renewals; additional renewals may be approved by Minister (Maximum 7)
   Acquisition: Filing
   Total Bonus Amount: n/a
   Titleholders: Epic Resources B.C. Ltd. — 100%
   Hectares: 7,144
   Current Rental: $3,572.00
   Note: Cancelled July 29, 1990

5. **Permit 3157 — Class "A" — General Area: Chilliwack**
   Issue Date: March 1, 1989
   Term: 1 year with 4 one year renewals; additional renewals may be approved by Minister (Maximum 7)
   Acquisition: Filing
   Total Bonus Amount: n/a
   Titleholders: McLean Oil & Gas Limited — 100%
   Hectares: 7,607
   Current Rental: $3,803.50

6. **Permit 802 — Class "D" — General Area: Delta**

Issue Date: October 23, 1957
Term: 1 year with 7 one year renewals; additional renewals may be approved by Minister
Acquisition: Filing
Total Bonus Amount: n/a
Titleholders: Conoco Canada Limited — 66.67%
Dynamic Oil Limited — 33.33%
Hectares: 21,988
Current Rental: Suspended

NOTE: The majority of this Permit (more than 17,000 hectares) is offshore. The remainder includes rights under the Fraser River and scattered small areas on land. It was originally issued to two individuals: John White and Elmer Palmer and, through transfers, has been held by various companies throughout the years, including Richfield Oil, British American Oil and Gulf Oil Canada.

Exploration work, including marine seismic and the drilling of a 14,793' well at Point Roberts, was carried out until 1970.

In 1970, because of opposition to *offshore* exploration, the province suspended the fee, rental and work obligations for the Permit and it has remained an inactive, but valid, permit ever since. In recent years, discussions have been held concerning the possibility of activating only the *non-offshore* portions of the Permit. There is no expectation of offshore exploration being allowed to proceed.

Source: Ministry of Energy, Mines and Petroleum Resources, 1990.

APPENDIX J

Comparisons of Spacing Requirements for Oil and Gas Drilling in Several Jurisdictions

In items 1 to 8, minimum distances in B. C. are compared with some of those in other jurisdictions where the other jurisdiction prescribes a limitation in its oil and gas statute.[1] In item 9, some requirements in other jurisdictions, not mirrored in the B. C. legislation are set out.

1. Road Allowance

B. C.	80m
Ontario	150 feet
Alberta	90-290m, depending on size of drilling spacing unit
P. E. I.	250 feet

2. Public Utility

B. C.	80m
Ontario	150 feet
P. E. I.	250 feet

3. Permanent Building, Structure or Works

B. C.	80m
Ontario	250 feet
P. E. I.	250 feet
Pennsylvania	250 feet

4. Place of Public Concourse

B. C.	80m
Ontario	250 feet
P. E. I.	250 feet

5. Reservation for National Defence

B. C.	80m
P. E. I.	250 feet

6. Mines and Underground Storage Facilities

B. C.	3km
P. E. I.	2 miles

7. Streams and Bodies of Water

B. C.	100m
Ontario	350 feet
Alberta	100m
P. E. I.	300 feet
Pennsylvania	100 feet

8. Domestic Water Supplies

B. C.	200m (test holes only; no requirement re wells)
P. E. I.	Domestic water well: 600 feet Municipal well: 1,000 feet
Pennsylvania	200 feet

9. Well-to-Well

Pennsylvania	1,000 feet (gas wells only)
Michigan	1,320 feet

[1] *Drilling and Production Regulation*, **B.R.O.** 1980, Reg. 752, s. 9
Oil and Gas Conservation Regulations, **A.R.** 151/71, ss. 2.120, 4.020
Oil and Gas Conservation Regulations, **R.R.P.E.I.** c. O-3, ss. 18-19
58 Pennsylvania Statutes 507, 601.205
Michigan Regulations 299.1201 (c).

APPENDIX K

Excerpt from Textbook by Donald Katz and Robert Lee Natural Gas Engineering — Production and Storage[1]

14.4 SAFETY AND RISK

Risk is the possibility of loss or injury due to an incident in storage operations. Natural gas storage operations have two kinds of risk. The first risk has to do with the safety of people and property from harm due to explosions or fires resulting from uncontrolled gas losses or movement. The second risk is economic, the possible loss of unretrievable gas underground or into the atmosphere.

Safety

A consideration of safety must always put the total system in perspective. No one expects our highways to be perfectly safe, and although people work hard at reducing accidents, they are also forced to admit that accidents cannot be prevented altogether. All technology carries some degree of hazard, which should be minimized while at the same time making use of the technology. After an incident, investigation of the causes often leads to corrections, preventing it from happening again in the future. Good safety practice includes as thorough an anticipation of such happenings as possible and the making of the necessary corrections prior to the incident contemplated.

In long-range perspective, workmen or the public involved in the technology find that certain social costs are borne by them when appropriate corrective measures have not been taken. Not all hazards are contemplated and there can well be social costs or penalties found after the fact. It behooves each company or organization to do their best in minimizing such unforeseen events.

Odorization of Gases — A Safety Measure

Natural gases serving as domestic fuel in the United States must be odorized so that leaking gas may be detected by its odor. The requirement is that a gas concentration of 20 percent of the lower combustion limit will indicate its presence by smell, a safety factor of 5. This requirement applies to fuel gas in a gas distribution system, but may not apply to high-pressure transcontinental pipelines or distribution lines.

Odorants are organic compounds containing sulfur, usually mercaptans, disulfides, thioethers, or carbon sulfur ring compounds. They are marketed as liquids with densities of 0.8 to 1.0 g/ml, initial boiling points of 120-230 degrees Fahrenheit (49-110 degrees Celsius), Reid vapor pressures from 1 to 8 psia (6.89-55.1kPa), and molecular weights around 85. The odorization rate is in the range of 0.25 to 0.75 lb/MMcf of gas. Odorants increase the sulfur content by 0.07 grains/100 cubic feet for the 0.25 lb/MMcf of gas.

Odorizing stations often are situated at distribution pipelines' delivery points to towns — usually with pressure controls. Two methods are employed, injection or bypass odorizers. Since the gas flow being odorized is variable with time, the injection pump rate must be connected to the flow rate. The bypass system involves a sidestream of the fuel gas passing over liquid odorant to carry the vaporized odorant to the main fuel supply. The bypass rate is controlled by the fuel gas flow rate.

[1] McGraw Hill, New York, 1990, pages 584-588. Reprinted with the permission of Dr. Robert Lee.

LP gas (propane) is marketed as a liquid, often in cylinders. Here the odorant is placed in the liquid, which in turn gives off a vapor fuel with the proper odorant concentration. Ethyl mercaptan (C_2H_5SH) is used for this service at 1.5 lb per 10,000 gallons of propane. This concentration is 25 ppm by volume in the liquid and diminishes to 4.5 ppm at 32 degrees Fahrenheit (0 degrees Celsius) and 5.8 ppm at 90 degrees Fahrenheit (35 degrees Celsius) for the gas. A study of the detection of odor in propane vapor was made in the Bartlesville Research Centre of DOE in 1977 [14-17].

A 30-to-50-Year Lifetime for an Underground Gas Storage Reservoir

Gas storage reservoirs developed either from original oil and gas reservoirs or aquifers may be expected to have a storage operation lifetime of 30, 40, or 50 or more years. There really is no reason to put a time limit on the life of the reservoir, assuming that gaseous fuel will be used indefinitely and that a given reservoir will not become an uneconomic venture.

From this time perspective, there is a reasonable possibility that over this period, gas from some of the wells will leak through the casing or cement to enter zones above the intended storage zone. A concern is that this gas eventually might reach water supplies and appear in the local user's water. Gas might even permeate the soil at the surface and enter homes or buildings to provide explosive mixtures.

Many precautions are taken to minimize and hopefully eliminate such gas leakage, but it is foolhardy to say that such leakage will not occur in a reservoir being developed with a projected 30-to-50-year lifetime. The question then may be raised as to what policies and activities should be carried on by the gas storage organizations to minimize the hazards to people and property involved, both the public and workers associated with the storage project. The gas storage industry has a good safety record with few serious accidents.

Land Use Plan

A variety of arrangements are made between the land owner and the gas storage operator relative to the land use. Some portion of the land is normally purchased by the gas storage operator to be used for plant sites or, in some cases, the entire surface may be purchased. Storage rights for the underground strata may be purchased along with rights of ingress and egress for pipelines and wells. For agricultural use, the latter procedure seems appropriate, provided attention is paid to water supplies and particularly the basements of the homes in the area of the gas storage reservoir. Would gas entering the water supply of a given residence cause combustible gas mixtures to accumulate in the home and provide a hazard? Double-tank pump systems with intermediate venting may be used. It would be preferable to have the homes on concrete pads without basements, and this type of new construction might be well advised in gas storage areas. Monitors in basements that would detect low concentrations of natural gas could possibly be installed to provide adequate warning before gas reached the explosive limit, should gas ever enter a basement.

On occasions, gas has bubbled through low ditches or ponds and permeated the soil, causing damage to vegetation. However, adequate recompense can be made for such damage and it is not the type of hazard of concern here, since the presence of the gas would be obvious, permitting corrections and the recompense.

Managers of gas storage fields adjacent to villages or cities should be concerned if subdivisions are planned in the storage area, or close enough to wells so that any leak is as likely to cause an incident in a home as to be detected by the monitoring procedures.

Would it be possible to include an agreement in the purchase of the storage zone that the land would not be converted from agricultural to residential use? Probably not, but many operators learn to cope with urbanization of storage field areas by monitoring.

Recommended Policies

It is recommended that a policy of storage acquisition and operation be followed to permit the maximum control over hazards should some leak occur in the storage field. A monitoring procedure with annual review of the situation in each field should be followed, with all parties to the storage operation in attendance. Follow-up checks should be made to see that decisions from the review meetings are carried out. Likewise, attention should be given to casing strings, annulus pressures, and corrosion in wells. Review of pressure observations in the monitoring of water zones above the storage level also is important and should continue with a high level of precaution.

Ownership of the land by the storage operator, with subleases for agricultural use or other appropriate land uses, appears to be a good policy when it does not bear an undue economic burden. Acquisition of land in the storage area might be carried out for fields currently in operation. Any land in the storage area that enters the market through the normal course of events might then be procured, especially if there are residences near any facilities. Education programs for the residents of the area, along with monitoring of water streams, is important. Early reporting of any unusual happenings that might be construed as evidence of gas in the soil or water should be encouraged, and appropriate means for this reporting should be provided.

Effect of Earthquakes on Water Level Variations

A surprise observation is that water wells may be good seismographs, in that earthquakes at great distance can cause the water levels to bounce up and down. Following the Alaskan earthquake in 1964, water levels through the United States responded by level fluctuations as much as tens of feet as the earth waves passed the area. The levels of a good number of water zones had a permanent rise, varying from inches to five feet. This permanent rise is believed to be due to the settling of overburden on the aquifer, causing enough compression to reduce the porosity, thus increasing the fluid pressure. Figure 14-11 shows the nature of the water level recorder reading following an earthquake. Experiences of the USGS, assuring that such behavior did not represent storage gas movement, reinforce this theory [14-3].

Flags Indicating Need for Special Attention at This Time

From everyday reading of the papers, it is clear that environmental groups are finding occasions for bringing suits and injunctions for stopping certain operations. Any operator should be prepared that others may have an incident that may raise public interest or cause ardent investigators to review his precautions. Environmental impact statements are needed for storage field approval by the FERC, so there is a need for great detail in understanding the operations.

Caution must be exercised in claiming that no gas will ever be found outside the intended well-gathering line-reservoir system. If any gas is found outside the intended system, it is possible that it can be handled so as to cause little or no harm, and should be no cause for calling a halt to the operations. Therefore, it is necessary in any full description of a 50-year plus life for a storage operation to admit that, on occasions, some gas will enter the waters and even the soil, but to state that mechanical repairs are available so that the leak can be halted.

APPENDIX L

Excerpt From Report by Deloitte, Haskins & Sells

The Effect of Sour Gas Facilities on Property Values in the Crossfield, Okotoks, and Pincher Creek Regions of Alberta[1]

November 1988

The following is from a report on property values in the Caroline Swan Hills area.

1.3 Conclusions

The conclusions based on the statistical analysis of sales data are:

- **Crossfield Region:**
  - — The presence of sour gas facilities had no effect on agricultural property values.
  - — The presence of sour gas facilities had no effect on country residential/ recreational property values.
- **Okotoks Region:**
  - — The presence of sour gas facilities had no effect on agricultural property values.
  - — The presence of sour gas facilities had no effect on country residential/ recreational property values.
- **Pincher Creek Region:**
  - — The presence of sour gas facilities had no effect on agricultural property values.
  - — Country residential/recreational sales were not analyzed because insufficient sales occurred to enable analysis.

Overall, it is concluded that the presence of sour gas facilities had no effect on property values in general. The analysis of actual sales data did not indicate a statistically significant effect on property values for either agricultural or country residential/recreational properties, in any of the three regions.

Results of interviews with vendors, purchasers, and local authorities generally supported the sales data analysis, but also indicated that sour gas facilities may affect property values in some instances. However, any possible negative impacts would vary by the use of the property, the type of facility, and by the geographic region. Based on interview data, the properties most seriously affected are country residential properties, which are located downwind and within three to five miles of a sour gas processing plant. The interviews indicated that sour gas facilities have little or no effect on agricultural property values.

Results from the consultant's interviews with vendors, purchasers, and local authorities revealed a number of positive effects from sour gas developments. In some instances, particularly on agricultural land, the presence of a sour oil or gas well increased property values due to the petroleum lease revenue. The employment and business activity

generated by the oil and gas industry also had a beneficial impact on property values for the region as a whole. These benefits arose from: increased employment opportunities from both direct industry and spin-off businesses, an improved road system, and increased contributions to community and recreational projects. In addition, tax revenues associated with the oil and gas industry were considerable in all three regions.

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[1] Exhibit T-39, page 3.

APPENDIX M

Glossary

Abbreviations
Aquifer Storage
Blowout
Cable-tool Drilling
Caprock
Casing
Cementing
Closed Mud System
Cretaceous
Cushion Gas
Geochemical Survey
Groundwater
Hydrocarbons
Injection/Withdrawal Well
Natural Gas
Permeability
Porosity
Quaternary
Reservoir Rock
Rotary Drilling
Sedimentary Rock
Seismic Survey
Sour Gas
Spudding In
Sweet Gas
Tertiary
Trap
Tripping In
Underground Gas Storage
Well Log
Wire Line Log
Working Gas
Workover

Abbreviations:

BP — British Petroleum
Consortium — The Fraser Valley Gas Project
dba — Decibels
EMPR — Ministry of Energy, Mines and Petroleum Resources
Friends — The Friends of the Fraser Valley Ecological Society
ha — Hectare

Aquifer Storage: Storage of gas underground in permeable and porous rock stratum, that previously contained water. Approximately 15% of the 430 underground gas storage reservoirs in Canada and the United States are aquifers.

Blowout: A blowout is an uncontrolled flow of oil, gas, or water from a geological formation that a drilled hole has penetrated.

Cable-tool Drilling: An early method of drilling that involves a continuous striking of rock with the drill bit, which moves in an up and down motion. This form of drilling is used infrequently today.

Caprock: Rock that prevents the upward migration of oil or gas in the subsurface.

Casing: Large steel pipe that is run into the wellbore for the purpose of protecting other subsurface areas, such as groundwater zones. Surface casing is the first casing run into the hole, followed by intermediate casing, and if the reservoir is viable for petroleum extraction, production casing.

Cementing: The process of securing casing in place. Cement slurry is poured into the casing; this slurry is then forced to the bottom of the wellbore and up the side of the casing, where it dries.

Closed Mud System: A series of tanks above ground to contain all drilling fluids used in a drilling program.

Cretaceous: On the geologic time scale, a time interval between 70 and 135 million years before present.

Cushion Gas: Gas in an underground storage reservoir which is necessary for a minimum operating pressure. This volume of gas cannot be used for delivery. See Working Gas.

Geochemical Survey: Content analysis of hydrocarbons which provides a precise indication of subsurface petroleum accumulations.

Groundwater: Subsurface water.

Hydrocarbons: Molecules containing hydrogen and carbon atoms, and the principle components of petroleum. The chemical structure of hydrocarbons varies, and this in turn affects the characteristics of oil and gas.

Injection/Withdrawal Well: A well extending from the surface to an underground gas storage reservoir, used for either the input or withdrawal of gas.

Natural Gas: Lighter petroleum constituents that occur naturally in a gaseous form. The main component of natural gas is methane but it may also include traces of nitrogen, carbon dioxide, ethane, propane and other molecules. See Sweet Gas and Sour Gas.

Permeability: Ability of a porous structure to transmit fluid. Reservoir rock must have a certain minimum permeability for the purposes of petroleum extraction.

Porosity: Proportion of a porous structure that is occupied by voids. Reservoir rock needs to have a certain minimum porosity for the purposes of petroleum extraction.

Quaternary: On the geologic time scale, a time interval up to one million years before present.

Reservoir Rock: Subsurface rock that is capable of containing oil, gas or water.

Rotary Drilling: A form of drilling that involves a drill bit rotating firmly against the ground. While the drill bit is being turned, drilling fluids are forced out of openings in the bit to remove cuttings and to keep the bit exposed. Today, rotary drilling is the most commonly used drilling method.

Sedimentary Rock: Rock that is formed in layers, by deposits of rock particles carried into seas, lakes or rivers.

Seismic Survey: A method of collecting subsurface data through the creation of vibrations. It is generally one of the last surveys undertaken before any drilling, and provides fairly precise details on the subsurface.

Sour Gas: Natural gas that contains toxic hydrogen sulphide. Petroleum deposits known to contain hydrogen sulphide are frequent in Canada and elsewhere in the world. However, no traces of sour gas have been found in the Fraser Valley, and geologists do not believe that the requisite geological conditions exist for sour gas to be present.

Spudding In: Initial drilling of a well.

Sweet Gas: Natural gas that contains no hydrogen sulphide and is non-toxic. Geological and geochemical studies indicate that only sweet gas will likely be found in the Fraser Valley.

Tertiary: On the geologic time scale, a time interval of between 1 and 70 million years before present.

Trap: Geologic structure that prevents the escape of oil and gas from reservoir rock. The presence of a trap is necessary for the accumulation of petroleum deposits.

Tripping In: The resumption of drilling after the casing and cementing processes are finished.

Underground Gas Storage: The storage of natural gas in a natural subsurface reservoir. The purpose of such storage capacity is to supplement the steady supply of gas from a pipeline when demand exceeds supply, such as in winter months.

Well Log: A systematic recording of geological data gathered during the drilling or production of a well.

Wire Line Log: A device used to measure subsurface rock characteristics through electrical, acoustic and radioactive methods.

Working Gas: The volume of foreign gas injected into a reservoir that is capable of delivery. See Cushion Gas.

Workover: Repairs undertaken to maintain or increase the production of a producing well. Workover rigs are scaled-down drilling rigs.

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